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ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

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CABLE ADDRESS—TESTING

Number 152 | May 1948

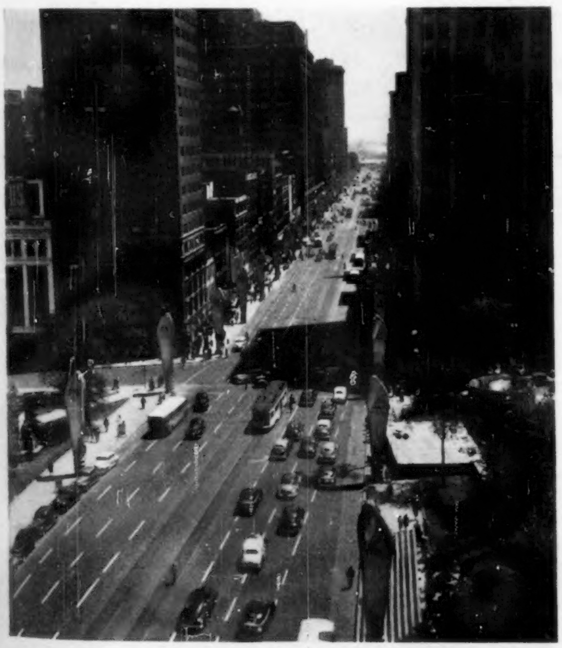
Extensive Technical Program, Committee Meetings, Exhibits, Features of 51st Annual Meeting

Eighteen Sessions, Over Three Hundred Committee Meetings, Apparatus and Photographic Exhibits in Detroit, Week of June 21

With eighteen technical sessions, more than three hundred meetings of the Society's various committees and two exhibits, one on apparatus and laboratory supplies, the other photographic, all scheduled for the week of June 21 in Detroit during the Society's 51st Annual Meeting, a very busy period is in store. There is no advance meeting registration this year to judge the number who will be going to the meeting, but from the hotel reservations which the Convention Committee is receiving in Detroit, there is no question but that this will be a heavily attended meeting.

Full details of the technical sessions are given in the Provisional Program in this BULLETIN (see page 17).

No advance schedule of committee meetings in composite form will be distributed by Headquarters. However, each technical committee secretary presumably will follow the customary plan and advise his members of the meetings scheduled. Early in April there was distributed to each member and committee member *a general outline of the sessions and days on which certain committees would meet* but at that time obviously no detailed schedule was available and some of the meetings listed were purely tentative.



Woodward Ave.—Toward the River.

Society's 51st Meeting

This will be the Society's 51st Annual Meeting. Organized in 1898 as the American Committee of the International Association, and officially incorporated in 1902, the Society will soon be celebrating its fiftieth year as a corporate organization. Detroit was the scene of the 1935 meeting, a most successful and interesting one, but this year the meeting is much more extensive in almost all respects, and it is necessary to schedule committee meetings and some sessions at other than the Book-Cadillac, the main headquarters hotel. Other meetings are being held at the Statler and Detroit-Leland, which are a very short walk from the Book, and several other hotels are cooperating with sleeping room accommodations.

Lecture on Use of Isotopes

A brief advance statement by Dr. Paul C. Aebersold, the 1948 Edgar Marburg Lecturer, appears on a following page together with biographical material on this distinguished scientist. The Lecture Committee was fortunate in securing a leader in his field to discuss isotopes and their application in the field of industrial materials. This is scheduled for Thursday evening at the Rackham Memorial Building in Detroit, and a capacity audience is expected. Following the Lecture proper there will

Provisional Program

A Study of the Provisional Program beginning on page 17 of this Bulletin is the best means for members to get a clear conception of just what sessions are planned and when. Synopses of the papers are provided and there are general statements on some of the symposiums. The final program available at the registration desks at the three hotels will contain the final details of the sessions, include a complete schedule of all committee meetings, and give data on the apparatus exhibit. Members will get the final program as they register at the Book-Cadillac (main headquarters), the Statler, or Detroit-Leland.

be a discussion period which is being instituted for the first time because of the interest in this subject. It is expected that certain Awards will also be made at this session.

Preprints of Reports and Papers

To each member in good standing there was mailed early in May a Preprint Request Blank which he could mark and return to A.S.T.M. Headquarters, thus making known his desire to have certain papers or reports that would be preprinted. This material probably will be mailed in three installments, the final one just before or during the Annual Meeting. Members attending the meeting can of course obtain, as they register, copies of preprinted papers and reports, or abstracts of items that it was not possible to preprint. *Preprints will be distributed at the Book-Cadillac.*

Medalists and Award Winners

At some appropriate part of the Annual Meeting the winners of the various awards will be recognized and presentation of the medals and certificates will be made. For their notable paper on "The High-Temperature Fatigue Strength of Several Gas Turbine Alloys," Messrs. N. L. Mochel and P. R. Toolin, of Westinghouse Electric Corp., will receive the 1948 Charles B. Dudley Medal, recognizing an outstanding contribution on research. The Richard L. Templin Award, which recognizes new work on testing methods and apparatus, will go to Messrs. G. S. Burr, W. J. Gailus, J. O. Silvey, S. Yurenka, and A. G. H. Dietz, for their paper on "Universal Plastics Testing Machine," and the Sanford E. Thompson Award sponsored by Committee C-9 on Concrete and Concrete Aggregates, will be awarded to W. C. Hanna for his paper on "Unfavorable Chemical Reactions of Aggregates in Concrete, and a Suggested Corrective." This year the committee responsible recommends that there be no Sam Tour Award.

Entertainment Program

The program of entertainment for the wives and families of A.S.T.M. members who will be in Detroit during the Annual Meeting starting Monday, June 21, has been completed. C. E. Heussner of the Chrysler Corp., member of the General Committee on Arrangements, is functioning as chairman of the Annual Dinner and Ladies' Entertainment. Mr. Heussner, who has been ably assisted by a Hostess Committee headed by Mrs. T. A. Boyd, has announced the following activities for the week of the meeting.

A get-acquainted tea has been arranged for Monday, at the Hotel Statler.

Tuesday there will be a luncheon at the Dearborn Inn followed by a trip through the adjacent famous Greenfield Village. The Village with the Ford Museum depicting early American history is one of the country's most popular historical centers.

On Wednesday, June 23, arrangements have been made for a breakfast at the J. L. Hudson Company Department Store, where a Fashion Show will be presented.

The Annual Banquet on Wednesday evening will emphasize the social aspects rather than the usual more serious A.S.T.M. activities. Following the annual address by A.S.T.M. President T. A. Boyd, Research Consultant, of General Motors Corp., the remainder of the evening will be given over to dancing. From the interest shown this promises to be an event of note.

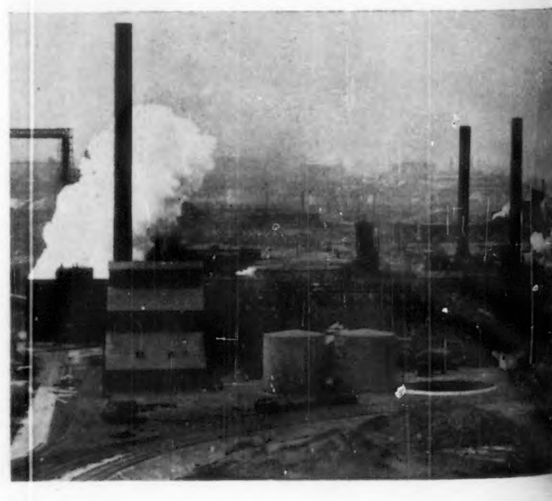
Arrangements have been made for a tour of private gardens in the Grosse Pointe area on Thursday in conjunction with a luncheon at the Detroit Yacht Club.

Local Committee

Under the auspices of the A.S.T.M. Detroit District Council, a local Committee on Arrangements is handling various phases of the meeting. The personnel of the groups follows:

Detroit Council Officers:
- *Chairman*, V. M. Darsey, Parker Rust-Proof Co.
- *Vice-Chairman*, F. P. Zimmerli, Barnes-Gibson-Raymond Div., Associated Spring Corp.
- *Secretary*, C. E. Heussner, Chrysler Corp.

Local Committee on Arrangements:
- *Honorary Chairman*, T. A. Boyd, General Motors Corp., President of the Society
- *Honorary Vice-Chairman*, A. E. White, University of Michigan, A.S.T.M. Past-President
- *Chairman*, C. H. Fellows, Detroit Edison Co.
- *Vice-Chairman*, V. M. Darsey, Parker Rust-Proof Co.
- *Secretary*, H. A. Wagner, Detroit Edison Co.
- *Subcommittee Chairmen:*
  - Annual Dinner and Ladies' Entertainment—C. E. Heussner, Chrysler Corp.
    - Hostess Committee—Mrs. T. A. Boyd
  - Apparatus Exhibit—J. L. McCloud, Ford Motor Co.
  - Photographic Exhibit—Frederick C. Weed, Rinshed Mason Co.
  - Publicity and Promotion—F. C. Kennedy, U. S. Rubber Co.
  - Hotels—C. M. Gambrill, Ethyl Corp.
  - Plant Visits and Local Transportation—F. P. Zimmerli, Barnes-Gibson-Raymond Div., Associated Spring Corp.
  - Finance—B. C. Case, Hanson-Van Winkle-Munning Co.



An Industrial Scene in Detroit.

Technical Sessions—Papers and Reports

Some very extensive symposiums are scheduled for the meeting and in fact each of the nineteen sessions will be a full one and interesting to the group concerned. Some general notes on the sessions follow, but more complete details will be found in the Provisional Program in this BULLETIN.

There are sessions at the Annual Meeting on the following topics:

- Magnetic Testing
- Usefulness and Limitations of Samples
- Deformation of Metals
- Effect of Temperature on Metals
- Corrosion of Ferrous Metals
- Tests for Ball Bearing Greases
- Waterproofing, Brick, Masonry Materials
- Fatigue—Ferrous Metals
- Mineral Aggregates
- Corrosion of Pressure Vessels
- Methods and Speed of Testing
- Identifying Reactive Materials
- Fuels, Fire Tests, Building Construction
- Creep and Fatigue—Non-Ferrous
- Cement, Concrete, and Concrete Aggregates
- Rubber, Plastics, Insulating Oil, Engine Antifreeze

This year the Committee on Papers and Publications in planning the meeting has reverted to the former scheme of having reports and papers presented together at the respective sessions. For the past two or three years special report sessions were developed in order to concentrate business matters, but this system has not worked too satisfactorily, in general due to the extremely small attendance at these sessions. While studies are under way to clarify or streamline business actions at the Annual Meeting, this year the existing regulations will be in effect.

Ultrasonic Testing:

The Round-table Discussion on Ultrasonic Testing scheduled for Monday evening at the Book-Cadillac is under the auspices of Committee E-7 on Radiographic Testing, which group is recommending an expansion in its scope to include other nondestructive tests. The use of ultrasonics tests in evaluating soundness of materials, particularly ferrous and non-ferrous metals, has grown rather extensively, and the round table will afford a good opportunity to compare techniques and results in various companies and in different fields. Invitations to participate in the discussion are being extended by Committee E-7 to a number of men who have been using the ultrasonics system.

Metallography in Color:

The Symposium on Metallography in Color developed under the auspices of Committee E-4 on Metallography will be of intense interest to all those who have been using this tool. Acknowledged leaders in their field will participate, and the six technical papers will give an excellent over-all viewpoint of the developments and applications of metallography in color.

Usefulness and Limitations of Samples:

While many of the Society's technical committees and other groups have devoted some attention to the importance of careful sampling, more intensive studies, it is felt, should be made, and Committee E-11 on Quality Control of Materials believes that its symposium with several specific papers will not only shed light on some of the problems but will also stimulate more interest in the need of careful sampling.

Quality Control Film:

On Tuesday afternoon at the Book-Cadillac, Simon Collier of the Johns-Manville Corp., will give his lecture on Quality Control and show his interesting sound color film which was developed to outline the basic principle of statistical quality control. This film should be of interest to any A.S.T.M. member.

Magnetic Testing:

For many years Committee A-6 on Magnetic Properties has arranged for the presentation of technical papers as part of its program in developing specifications and tests. With the steadily growing interest, the committee felt a symposium at the 1948 meeting would be in order. There are ten technical papers covering various aspects. The committee has enlisted participation of many acknowledged authorities in the field. This symposium is in two sessions, on Tuesday morning and afternoon, at the Book-Cadillac.

Deformation of Metals:

Deformation of metals as indicated by ductility or formability tests is extremely important in many fields. At no time was this more apparent than during the intensified production efforts of the recent World War. The Society's Administrative Committee on

Important Notes on Registration

THIS is the first Annual Meeting with three places for registration. Since there are many committee meetings at the Statler and Detroit-Leland in addition to the Book-Cadillac, and some technical sessions at the Detroit-Leland also, it was felt desirable to have auxiliary registration facilities available. Consequently members can register and get their official program at either the Book, the Statler, or Detroit-Leland.

All exhibits, most of the technical sessions, and as many committee meetings as possible are being arranged for the Book-Cadillac.

Register as soon as you can in Detroit.

A visible index of registration will be maintained at the Book, where also will be a complete card file of all members registering at any of the three hotels.

Downtown Detroit—Campus Martius.

Simulated Service Testing feels therefore that this symposium which it is developing is timely and that much help should come from the symposium and discussion. Topics to be covered involve sheet metals, materials used in ships, bulge testing, the effect of multiaxial stresses, and predicting of formability on the basis of materials properties.

Effect of Temperature on Metals:

Under the auspices of the Joint Committee on Effect of Temperature on the Properties of Metals which functions under the auspices of The A.S.M.E. and A.S.T.M., a session is being held on Wednesday morning in the Detroit-Leland. Several papers of considerable significance are being presented as well as the committee report. Graphitization susceptibility of certain steels with molybdenum and chromium is to be covered. There will be valuable data presented on creep and other characteristics of high-temperature bolting materials and an extensive contribution on the properties of gas turbine disk materials. The paper on properties of bolting materials is of particular interest since it will provide data that in many respects were sorely missing during the World War when alloy steels for bolting were not only difficult to obtain but properties of the alloys available had not been as carefully studied as was desirable.

Corrosion:

This session, Wednesday afternoon at the Detroit-Leland, involves the corrosion of various metals, and includes papers on testing of low-alloy steels; laboratory tests of pipe; the use of organic coatings for preventing corrosion fatigue failures, and others. Heat-resisting cast iron is covered as well as experimental studies on fracture of metals.

Ball Bearing Greases:

In arranging this symposium on functional tests for ball bearing greases, Technical Committee G on Lubricating Grease which functions as a division of A.S.T.M. Committee D-2 had in mind as one of its objectives developing and recording data that would broaden the background in guiding the design of the testers and interpretation of the test data. Consequently, the committee has obtained basic discussions on grease, functional tests in use, and description of some grease testing machines, and a paper on service experience with grease. There is also discussion of some simulated service tests.

Creep and Fatigue:

Of interest to the metallurgist particularly will be sessions on fatigue of ferrous metals, Thursday morning at the Detroit-Leland, and a Friday morning session at the same hotel involving non-ferrous metals, and including creep as well as fatigue. There are several significant papers and reports.

Mineral Aggregates:

A most extensive symposium on mineral aggregates has been arranged through the work of Committee C-9 on Concrete and Concrete Aggregates. The fourteen technical papers cover the field completely from questions of distribution of aggregates to needed research, with other papers covering mineralogic characteristics, significance of tests, sampling, grading, etc. The influence of aggregates on the strength and durability of concrete is one topic; others are discussions of various types of aggregates for specific applications such as bituminous construction, railroad ballasts, etc. This session is Thursday morning at the Book.

Corrosion of Pressure Vessels:

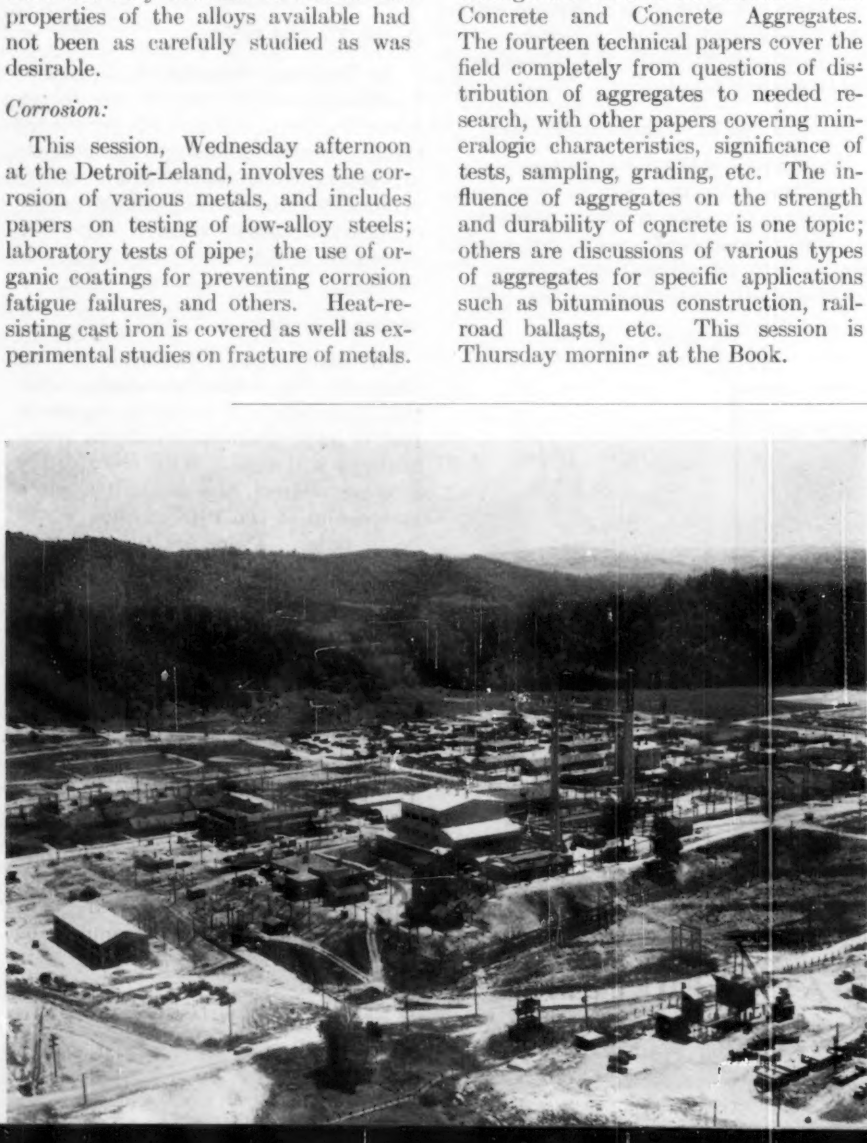
The influence of non-ferrous metals and their compounds on the corrosion of pressure vessels is the subject of a panel discussion Thursday morning at the Book under the auspices of Committee D-19 on Water for Industrial Uses. The importance of station design and composition of materials in boiler corrosion is to be covered. There is another basic paper covering factors which influence boiler corrosion, and the third formal contribution will relate to the effect of iron oxide and copper deposits in steam generating tubes.

Speed of Testing:

Under the auspices of Committee E-1's Section on Speed of Testing, there is to be a symposium on this subject Thursday afternoon at the Book-Cadillac. The effect of speed of testing of various materials is up for consideration including steel, magnesium-base alloys, wood, plastics, and a general paper on methods and equipment for controlling the speed.

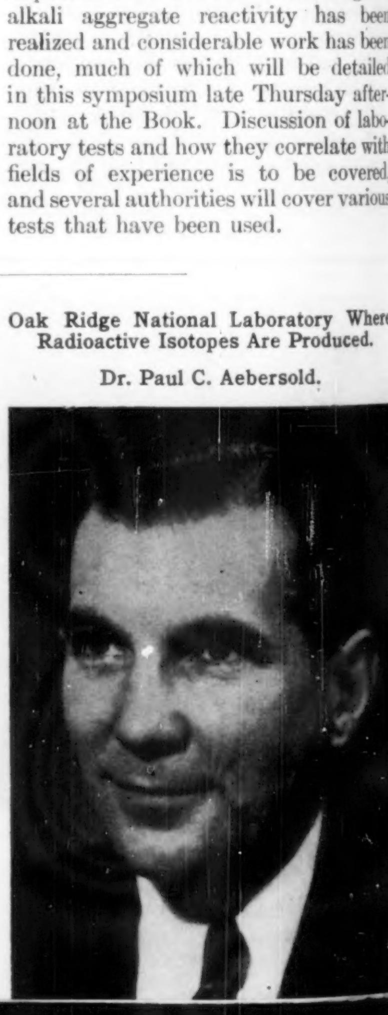
Reactive Materials in Concrete and Concrete Aggregates:

In addition to the Symposium on Mineral Aggregates, Committee C-9 has arranged another symposium dealing with the identification of reactive materials, and six technical papers dealing with test methods and procedures. The importance of a better knowledge of alkali aggregate reactivity has been realized and considerable work has been done, much of which will be detailed in this symposium late Thursday afternoon at the Book. Discussion of laboratory tests and how they correlate with fields of experience is to be covered, and several authorities will cover various tests that have been used.



Oak Ridge National Laboratory Where Radioactive Isotopes Are Produced.

Dr. Paul C. Aebersold.



1948 Marburg Lecturer will be Dr. Paul C. Aebersold

Chief of the Isotopes Div., Atomic Energy Commission, Oak Ridge, Tenn., to Discuss Industrial Applications of Isotopes

It would be a trite statement indeed to say that the 1948 Edgar Marburg Lecture on the subject "Isotopes and Their Application in the Field of Industrial Materials" is a timely one. It is of course that, but much more. It is the question of the hour; in fact the subject involves a whole host of questions. Some of these will be answered and discussed at the 1948 Edgar Marburg Lecture by Dr. Paul C. Aebersold, Chief of the Isotopes Div., Atomic Energy Commission, Oak Ridge, Tenn.

Many of the country's leading scientists, and materials men are actively engaged in determining whether radioactive isotopes and stable isotopes can help in analytical, research, testing, and production problems. Dr. Aebersold in an advance statement on his lecture prepared for this Bulletin points out that the radioactive isotopes are probably the most constructive result of nucleur research. That statement by itself should be sufficient to indicate the timeliness of the subject for an A.S.T.M. meeting.

The Lecture is to be given at 8 p.m. on Thursday, June 24, at the Rackham Engineering Building in Detroit. Following the Lecture there will be a general discussion, the first time there has been a discussion period following these lectures. Members are urged to get to the meeting early because a capacity audience is expected.

Statement on 1948 Marburg Lecture

The advent of radioactive isotopes has probably been the most constructive contribution to fundamental and applied science yet realized by the many and varied phases of nuclear research. Radioisotopes are only one of several kinds of "fruit ripening on the tree of atomic energy" but one which has "ripened" sufficiently for present-day consumption. Their application as research tools in such fields as medical therapy, animal and plant physiology, bacteriology, chemistry, physics, metallurgy and industrial research is even now well known and appreciated by many investigators. The availability of these materials in their present abundance has resulted from the wartime development of the chain reacting pile.

The use of isotopes in the field of industrial materials is potentially a great one. As tracer atoms they may be used in research aimed at improvement of material and increased efficiency of production. They are already being used widely in investigations covering such varied topics as friction, oil well logging, ventilation, steelmaking, vulcanization, polymerization, welding, corrosion, catalysis, diffusion, chemical exchange and pharmaceutical syntheses.

Tracer atoms may also be used in routine process control. Such uses are largely still in the development stage. In the case of process use of radioisotopes, the handling methods and levels of activity would have to be safe from the standpoint of industrial hygiene and public health. Incorporation of unsafe amounts of activity in marketed products would have to be avoided. Stable isotopes would not involve health-safety problems but they would not in general be as readily adaptable to continuous process measurement.

Tracer techniques can be used to give accurate quantitative as well as rough qualitative results. Radioisotopes are measured with instruments such as electroscopes, ionization chambers and Geiger-Mueller tubes. In some instances, however, as in friction studies, autoradiographic techniques are being satisfactorily substituted. Stable isotopes are best measured with a mass spectrometer.

The wide scope of radioisotope application is permitted by the fact that radioactive isotopes are now available of most of the elements. This list includes such metallic elements as calcium, copper, iron, cobalt, nickel, silver, tin, zinc, tungsten, gold, and bismuth. Also available are radioisotopes of such nonmetallic elements as carbon, phosphorus, bromine, chlorine, and sulfur.

Electromagnetically concentrated stable isotopes of elements from lithium to lead have recently become available. Certain elements not having radioactive isotopes which are useful for tracer studies can be traced with stable isotopes; oxygen, nitrogen, and boron are examples. Limited application of stable isotopes at present is accounted for by the previous scarcity of the concentrated materials and by the necessity for measurement with a mass spectrometer.

Radioisotopes can also be used to provide radiations for special uses in material processing, such as for radiography, liquid level indication, thickness control and static elimination.

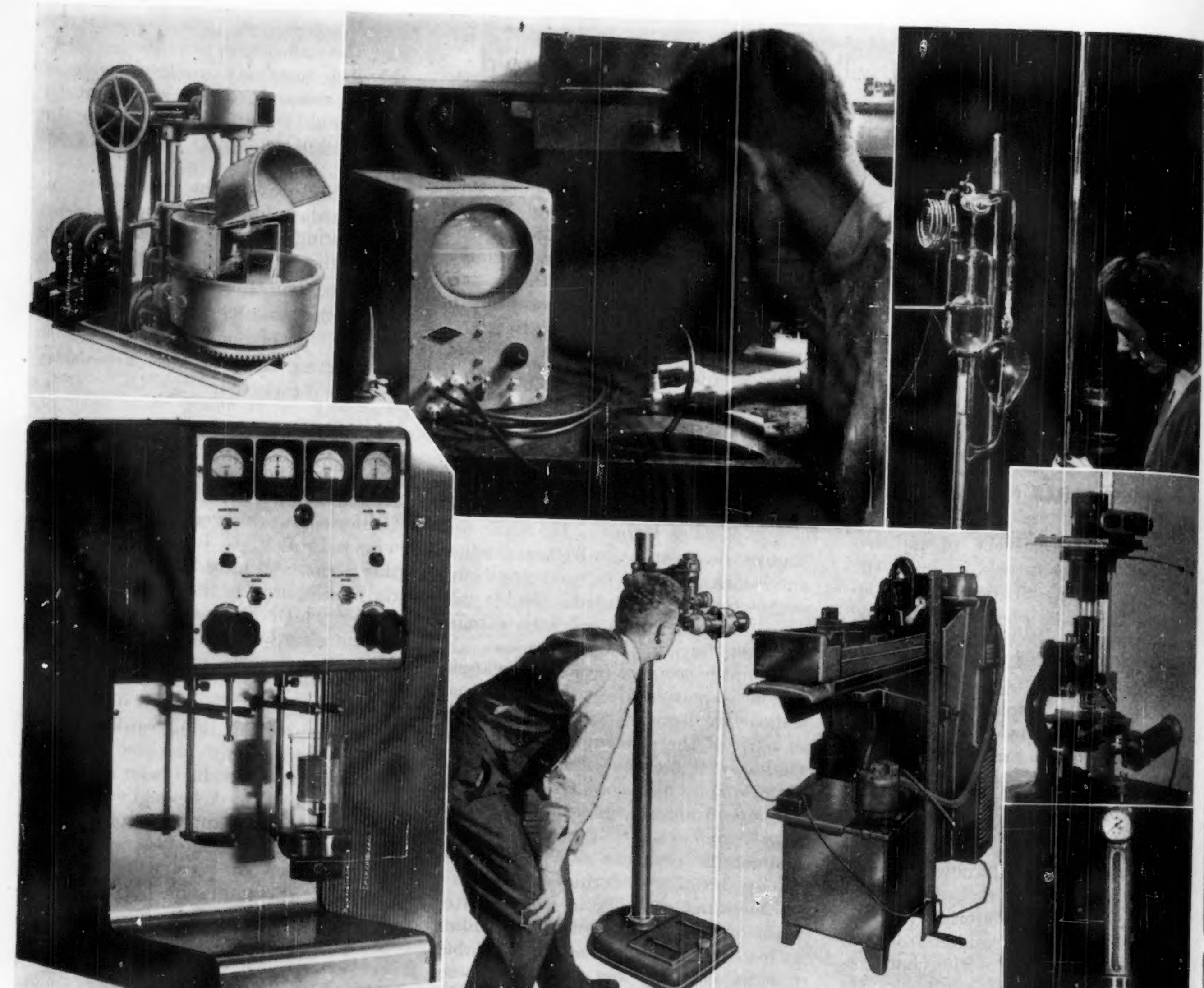
Information concerning the handling and application of isotopes is becoming increasingly available. New applications and new successes will come with improved techniques of using this type of tool. Many of these applications are now beyond the realm of our conception; many of them will lend themselves to no other method of attack.

About the Lecturer, Dr. Paul C. Aebersold

Paul C. Aebersold was born in July, 1910, in Fresno, Calif. His A.B. degree was received from Stanford University in 1932, and subsequently he did graduate work at the University of California, working under Nobel Prize winner Prof. E. L. Lawrence. During this period and later he participated in the development of the Radiation Laboratory which became one of the outstanding nuclear physics centers. His M.A. degree was received from the University of California in 1934. Following this he concentrated in the field of medical physics, doing work with the million volt X-ray machine. Meanwhile the cyclotron had been increasing in power and Dr. Aebersold cooperated in producing and applying some of the first induced radioisotopes.

Dr. Aebersold received his Ph.D. degree at the Radiation Laboratory in 1938. In 1940, as Research Associate, he was placed in charge of the 60-in. cyclotron which began to operate with 32 million volt alpha particles. The first man-made quantities of plutonium resulted from the 24-hr.-a-day use of this cyclotron. Early in 1942, Dr. Aebersold became a special administrative aid to Professor Lawrence to expedite the U 235 program. Later he was head of the Information Division and was concerned with patents and with health and safety problems. In 1944, Dr. Aebersold came to Oak Ridge where he served as Technical Consultant on many of the problems of research, operation, and health safety tied in with most phases of the project. He was called to Los Alamos in 1945 for work on health problems there, and he was active in connection with the assembling of the atomic bomb and made extensive after-explosion tests. In 1946 he returned to Oak Ridge and one of his jobs was the coordination of the supply of isotopes with demand and to stimulate understanding between all groups involved in the production and distribution program.

A prolific writer Dr. Aebersold has prepared many technical papers and reports in his field.



Members Will Find Much of Interest in Exhibits

Leading Apparatus Manufacturers and Distributors Will Show New Instruments and Latest Equipment; Photographic Exhibits Also Scheduled at Book-Cadillac

From the previews of the list of equipment which will be on display in the various booths it is apparent that many new instruments and items of laboratory equipment and supplies will be shown throughout the week of the Annual Meeting when the Eighth A.S.T.M. Exhibit is under way. Brief descriptions of equipment to be in the booths appear on the following pages. Invitations to attend the Exhibit are extended to all members and committee members, and the engineering fraternity and others interested in the Detroit and Michigan areas are receiving notice of the Annual Meeting and Exhibit. Anyone concerned with research and testing instruments, or with laboratory equipment, will find in this Exhibit an outstanding opportunity to get a real concept of developments in the apparatus field.

In addition to the new and improved machines for mechanical testing, a great deal of electrical and other physical testing apparatus will be on display, and various systems for nondestructive testing and inspection will also be featured.

This Exhibit, now on a two-year basis, has proved to be a very desirable adjunct to the Annual Meeting. Through the work of the Society's technical committees many new instruments and equipment have been developed and there are constantly coming out of the standardization activities new demands for various types of instruments.

This Exhibit affords the commercial organizations in this field an opportunity to point out the particular features of their products and also to ascertain from the members and visitors to the Exhibit some of the needs that are constantly developing for new or modified apparatus.

Two exhibit rooms are being used, the Grand Ballroom and the Italian Garden, each adjacent to the other and to the main A.S.T.M. Headquarters Registration Desk. Exhibit hours are as follows:

Monday—12 noon (opening) to 9:30 p.m.
Tuesday—9:30 a.m. to 9:30 p.m.
Wednesday—9:30 a.m. to 6:00 p.m.
Thursday—9:30 a.m. to 6:00 p.m.
Friday—9:30 a.m. to 12 noon (closing)

Photographic Exhibit

The 1948 Photographic Exhibit and Competition will really be in three parts: a General Section devoted to the subject, Materials—Testing and Research; and two other divisions, one dealing with Photomicrography, under the sponsorship of Committee E-4, and the other on Radiographic Testing sponsored by Committee E-7. Each of these technical groups has arranged interesting displays in previous years and this year they should be of even more interest. The Photographic Exhibit is being arranged in various portions of the same rooms used by the Apparatus Exhibit, and the prints and entries can be viewed during the Exhibit hours.

Committee Exhibits:

Some of the A.S.T.M. technical committees are planning to arrange displays and while there may not be as many as in previous years those that are developed will be well worth studying. The Exhibit Directory which will be a part of the final meeting program available at the registration desk will give full details of all exhibit matters.

Illustrations of Typical Equipment to be Displayed in the 1948 A.S.T.M. Exhibit of Testing Apparatus and Related Equipment, Hotel Book-Cadillac, Detroit, June 21–25 incl.

←

Top Row, Left: One of a Line of Precision Mixers Ranging from Laboratory to Production Equipment, Using the Counter-Current Mixing Combination; Center: An Instrument in Growing Use for Measuring Thickness, in this Case Used on a Propeller Section; Right: Rapid Carbon Determinator for Use in the Field of Metals and for Other Materials. Center Row, Left: Electro-Analysis Apparatus for Rapid Determination of Many Elements; Center: Measure-Scope for Precise Physical Measurements, in this Case Measuring the Straightness of Travel of a Small Surface Grinder; Right Top: A Newly Developed Micrographic Camera for 35-mm. Film; Bottom: A New Inlaid Air Indicator for Fresh Concrete Mixtures Using a Pressure Method.
Bottom Row, Left: A Moisture Determininator for Measuring Percentage of Moisture on a Variety of Substances; Center: A Polarograph for Rapid and Accurate Laboratory Determinations; Right: A 60,000-lb. Universal Hydraulic Testing Machine for Tension, Compression, Transverse, and Related Tests.

Machine, low range air cell, microformer stress-strain recorder, strain rate pacer, Lazan Oscillator, SR-4 load cell, SR-4 pressure cell, and bending beam; as well as a group of smaller measuring instruments. Newest among these are the Sonntag SF-4 High Temperature Fatigue Machine, and the 5000-lb. M. T. E. Universal Machine. These new pieces of equipment will be on exhibit for the first time. The Baldwin booth will be staffed by experienced men to demonstrate the complete line.

Bausch & Lomb Optical Co.
Booth 33

A number of interesting new spectrograph accessories will be featured in this booth. Here are some of the instruments that will be on display: a high-grade, self-contained densitometer that can be used either for direct reading or with a commercial recorder; a briquetting press for preparing compressed solid samples from powders, chips, and other finely divided materials; a spectrum plate projector; an electrode shaper for forming the tips of graphite electrodes; and a safety arc and spark stand providing complete protection when using high voltage alternating current and including an optical system and selective diaphragm as integral parts.

Brookfield Engineering Laboratories, Inc.
Booth 27

In this booth will be shown a standard line of indicating viscometers, automatic viscosity controller, and counter-rotating laboratory mixer.

Buehler, Ltd.
Booths 9, 10

The feature of the Buehler, Ltd. exhibit in Booths 9 and 10 will be the Swiss made Amsler testing machines and the Chevenard micro testing machines. Amsler machines accommodate standard size test specimens while the Chevenard machines are designed for the testing of very small samples.

Various examples of the complete Buehler line of metallographic sample preparation equipment will also be in operation, including the Buehler-Waisman Electrolytic Polisher, mechanical polishers, specimen mount press and metallurgical microscopes.

Burrell Technical Supply Co.
Booths 57, 58

In these booths there will be a wide variety of new and improved items for the analytical laboratory. In the gas analysis field, two new Burrell developments will be shown—the Burrell CO_2 Indicator and the Burrell Industro Gas Analyzer. These instruments are simple, accurate, and easily manipulated devices for analyzing certain constituents of gas mixtures. The standard Burrell gas analysis apparatus for the complete analysis of gases by the Orsat method will also be exhibited. Recent improvements in Burrell gas analysis apparatus are the catalytic assembly for combustible mixtures, the Perma-Therm heater for automatic control of combustion temperatures, and the availability of ball and socket joints on certain types of apparatus. Several new styles of Burrell high-temperature furnaces will be exhibited, including the "unit-package" tube furnace and a new "unit-package" box furnace. The Burrell "wrist-action" shaker relieves that tedious flask shaking job. For oxidation-reduction titrations, the Larrabee Titrater—a completely redesigned unit of extreme interest to steel chemists—will be shown. The Barrett coal ash fusion furnace, designed originally to simplify the determination of coal ash fusion according to the latest A.S.T.M. Method D 271, has been further streamlined and is also offered as a "unit-package" furnace. There will be many miscellaneous items of interest to all chemists and analysts.

Carboloy Co., Inc.
Booth 17

This Company will exhibit many wear-resistant applications of their material which will give the people, attending the exhibit, some idea of the broad fields of use. Carboloy products to improve their production method or machine parts and instruments. Part of the exhibit will have a display of some of the physical characteristics of Carboloy Cemented Carbides. These characteristics will be helpful in stimulating ideas as to where Carboloy material can be used.

Central Scientific Co.
Booth 25

Among the items in the Cenco booth is the new Entrained Air Indicator for measuring the percentage of air entrained in fresh concrete mixtures by the pressure method suggested by W. H. Klein and Stanton Walker, and further developed by C. A. Menzel. Exceptional features include: a unique clamping arrangement; the precision bore, glass measuring tube graduated from 0 to 8 per cent air in 0.1 per cent divisions; drawn steel plated bowl to resist abrasion; metal rodding tool provided with a hard rubber tip to prevent damage to the bowl; a metal sleeve around the glass gage to protect it; the round bottom of the bowl to allow for easy rotation and inclination of the vertical column to remove entrapped air bubbles. Numerous other instruments and equipment for the research and testing laboratory will be demonstrated.

Clark Instrument, Inc.
Booth 20

In addition to exhibiting the standard "Rockwell type" Clark Hardness Tester the new "S" model for superficial, testing will be introduced. This testing machine is used for testing the hardness of soft and thin metals, on the "N" and "T" Rockwell scales.

Consolidated Engineering Corp.
Booths 38, 39

This exhibit will feature two new instruments in demonstration. The first, the Consolidated Leak Detector, is for testing vacuum and pressure systems for leaks of any size down to 10^{-9} cc. per sec. This Leak Detector operates on the mass spectrometer principle being adjusted to extreme sensitivity of helium gas, which is used as the testing medium.

The other instrument is the new 36 trace Consolidated Recording Oscillograph which is featured with the various Static-Dynamic Measuring and Recording Systems produced by Consolidated. This new oscillograph incorporates the type 7-200 series of Consolidated Galvanometers, an extremely sensitive and very small galvanometer which will be shown in detail in cutaway instruments under magnification. In addition to the oscillograph, additional pieces of Consolidated equipment related to it will be in operation.

Models and large photographs will be used to show the Consolidated line of Mass Spectrometers including the large analytical Mass Spectrometer used by the major petroleum and chemical companies and the new Consolidated-Nier Isotope-Ratio Mass Spectrometer being used by cancer and biochemical research laboratories.

Corning Glass Works
Booth 47

Corning Glass Works will display "PYREX" brand laboratory glassware relating to A.S.T.M. tests. Other items of interest will be ball and socket joint apparatus, "VYCOR" brand 96 per cent silica glassware, and various types of filters incorporating fritted glass. There will also be a display on the new type photosensitive glass.

Detroit Testing Machine Company
Booths 19, 40

Displayed in these booths will be a hand-operated Brinell machine, direct reading power operated Brinell machine, Universal testing machine, tensile testing machine, ductility testing machine, portable tensile tester, and portable ductility tester.

Harry W. Dietert Co.
Booth 59

This company will exhibit the improved Dietert-Detroit Carbon Determinator which provides an easy method for making either preliminary or final carbon tests on all metals, organic or inorganic materials. This Determinator has the following advantages: Reliable: Results reproduced consistently—minimum chance for human error; Fast: Results available within 2 minutes after sample is weighed; Economical: Low first cost and low operating costs; Wide Range: Burettes available for low-carbon materials, steels, irons, and organic substances.

Eastman Kodak Co.
Booth 8

This exhibit will consist of a number of transparencies illustrating the use of Color Compensating Filters in metallography in conjunction with a direct-current carbon arc. There will also be on display a number of transparencies made on Ektachrome Film illustrating the use of polarized light in crystallography. On display will be a photomicrographic apparatus for studying the growth of crystals under the microscope utilizing polarized light. The industrial radiographic part of the exhibit will consist primarily of transparencies illustrating both conventional and new applications of x-ray radiography, microradiography, and x-ray diffraction. Of particular interest to the x-ray diffractionist will be a chart of "Kodak Films for X-Ray

Diffraction," tabulating the film speed, contrast, and graininess characteristics of five suitable x-ray materials. A set of x-ray diffraction films illustrating the chart data will be shown.

Eberbach & Son Co.
Booths 44, 45, 46

The Eberbach Electro-Analysis Apparatus for qualitative analysis of metals and the new Eberbach line of shaking machines will be featured by Eberbach & Son Co. of Ann Arbor in their exhibit of laboratory apparatus and equipment. The recently announced shaker line includes models for general purpose and flask shaking. An assortment of accessories enables the user to adapt these versatile machines to most any shaking job.

Gamma Scientific Co.
Booth 21

The booth of Gamma Scientific Co., will feature for the first time their now complete line of photomicrographic cameras. This includes, in addition to the well-known "Microflex" camera, a unit for use with 35-mm. film (black and white and color) and a "Fixed-Focus" camera, selling for less than $100. The latter will be welcomed by smaller laboratories whose limited photomicrographic work does not warrant the expenses of the more universal models. Also on display will be a Polarimeter which has only been recently introduced to the American market, Refractometers, and the famous "Sartorius" Balances. All weights from 10 mg. to 200 g. are permanently mounted inside of the Balance and are automatically applied by dials operated from the outside. The final reading is taken on a projection reader. Air Damping, which does not reduce the sensitivity of the Balance, reduces oscillations to a minimum. Also on display will be the new "Gamma" Textile Projector with electrically controlled specimen movement and other features.

General Electric Co.
Booths 15, 16

This exhibit by the G. E. Apparatus Dept. will feature two new products, the General Electric Ball Bearing Grease Tester and the General Electric Recording Vibrometer. Other equipment to be shown includes panel instruments, a photoelectric recorder, an electrostatic voltmeter, a hardness tester, AP-9 and AK-1 voltmeters, thermocouple vacuum gage equipment, exposure meters, a standard roughness scale, puncture tester, a-c. bridge, metals comparator, insulation resistance meter, and a winding insulation tester.

General Radio Co.
Booth 34

Among the instruments to be displayed will be a wide-range capacitance and power-factor bridge for measuring the characteristics of dielectric materials over a wide frequency range. This instrument permits the study of variations in dielectric constant and power factor from power-line frequencies to low radio frequencies with the upper limit in the vicinity of ½ megacycle. With this bridge will be shown an oscillator and a visual-type null detector. A new high-intensity light source for low-speed stroboscopy and short-flash photography will be shown. This new light source has an extremely high light intensity with a flash duration of about 10 microseconds. This flash time is about one-tenth that obtained with the newer commercial electronic speed lights, and consequently it can be used for scientific and industrial photography of subjects in rapid motion.. For stroboscopic work, it is useful in studying slow-speed mechanisms and particularly in analyzing machine motion as a function of the angular position of a shaft or other rotating member. Other General Radio products to be displayed include Variac autotransformers for voltage control, a megohm bridge for high resistance testing, and instruments for the measurement of noise and vibration.

Hanovia Chemical and Manufacturing Co.
Booth 24

This display will feature quartz mercury vapor arc lamps of the types used for laboratory testing, and transparent fused quartz in apparatus form. A particular feature of the exhibit will be quartz ware shaped to the designs described in a number of A.S.T.M. requirements. Also a highly sensitive ultraviolet meter for the measurement of the radiations of the mercury arc lamp will be shown. The mercury arcs will be of the type used for fluorescence tests and as luminesence for various optical instruments.

Illinois Testing Laboratories, Inc.
Booth 13

The following instruments will be on display in this booth: Pyrometers, New Almar Velometer Jr.—A Miniature Direct-Reading Air Velocity Meter, Almar dew point indicators, electrical resistance thermometers, thermoanemometers, Almar Pyrocon.

Kewaunee Manufacturing Co.
Booth 7

This company will exhibit samples of their recently designed steel furniture now in production. Data and samples of various materials for working surfaces, including Kemrock will be shown. Methods of evaluating and samples of special type protective coatings used on laboratory furniture of both steel and wood construction are included in the display.

Kimble Glass Division of Owens-Illinois Glass Co.
Booth 32

This exhibit will include representative items from the comprehensive Kimble line of laboratory glassware. Kimble Blue Line EXAX Retested, and Precision NORMAX Graduated ware, and Kimble K-Brand ungraduated ware will be shown. For the first time at an A.S.T.M. Exhibit, the Kimble display will include laboratory hydrometers and thermometers, now regularly listed in the Kimble Catalog of Laboratory Glassware.

King Refrigeration Co.
Booth 49

This company will display their Model 100 Cloud and Pour Test Cabinet which has proved very popular for testing oil in laboratories of small refineries, railroads and various other chemical laboratories. This cabinet consists of four sleeves at plus 30 F., four sleeves at 0 F., and two sleeves at minus 30 F. This cabinet has a self-contained, Freon Refrigeration Unit. Also on display will be a small, two sleeves minus 60 F. Cloud and Pour Test Cabinet to be used as a companion for a Model 100 Cloud and Pour Test Cabinet or for laboratories which will only require a small amount of minus 60 F. tests.

Laboratory Equipment Corp.
Booth 2

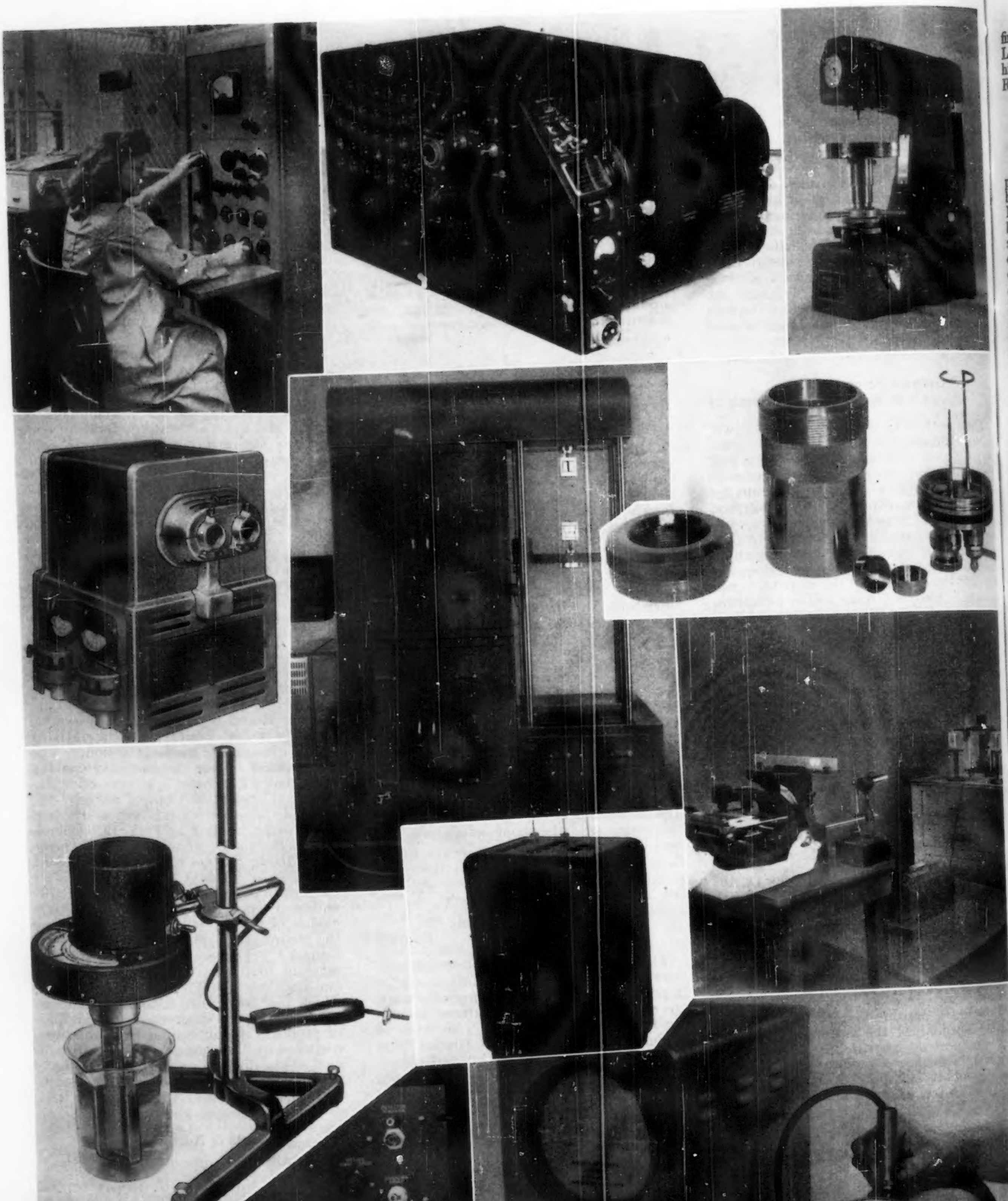
This company maintains a large research laboratory for the development of faster and more accurate methods of control in the metallurgical analysis field. Notable firsts in the field include, volumetric carbon determination, high temperature combustion-titration sulfur determination, extremely high-temperature combustion and low-cost combustion boats. A late development is an instrument for carbon analysis with a 0.0005 per cent accuracy. The latest refinements and developments of our research laboratory will be exhibited.

Lancaster Iron Works, Inc.
Booth 23

This display of "Lancaster" Mixers will be built around the theme that "Lancaster" Mixers represent the only system that provides Counter-current Mixing "plus" balanced mulling action. The background of our display develops the idea that "Lancaster" Mixers offer Industry (1) Scientific Control whereby the entire batch receives uniform and intensive mixing mulling action; (2) dependable performance in which the "Lancaster" Mixing System reproduces the same qualities in finished mixes, batch after batch with dependability; (3) wide adaptability is provided through the interchange of mixing tool elements to balance the action to requirements of different formulas; (4) operating economy through machine tool construction represented by cut tooth gears, and ball or roller bearings, which has been proved to contribute to lower power and maintenance. Samples of products manufactured from mixtures prepared in "Lancaster" Mixers will be a part of the display, and one or two "Lancaster" Mixers in laboratory size units will be featured.

Leeds & Northrup Co.
Booths 51, 52

Leeds & Northrup will display several instruments which are representative of their line of electrical measuring equipment for testing, standardizing and research. Among those featured will be a new, quick-reading microphotometer for routine spectrographic analysis; a new high-sensitivity galvanometer of the box type with integral lamp and scale; insulation resistance test set for dielectric tests in accordance with A.S.T.M. specifications; and the well-known Type K Potentiometer. Also on exhibit will be a number of L&N industrial instruments which



find wide use in laboratory work: the L&N Optical Pyrometer, and Speedomax high-speed Indicator and multiple-point Recorder.

Magnaflux Corp.
Booth 22

Some new methods, and the newer applications of non-destructive testing will be demonstrated. MAGNAFLUX AND MAGNAGLO inspection applications will be shown; the results of weld inspection as it is applied to process vessels, boilers, etc., and the type of MAGNAGLO fluorescent indications as they are automatically developed in modern high production, high-speed production control inspection. ZYGLO fluorescent penetrant inspection will be seen, as applied in non-ferrous inspection and in carbide tool control in production industries. The new MAGNAFLUX SONIZON in operation will be demonstrated. This ultrasonic automatic reading instrument will be applied to representative samples where critical wall thickness is measured from one side only and where internal laminar type defects are rapidly located, such as lack of bond in bearings, laminations in stock, or lack of adherence in laminar materials. Information on the new inspection methods using STATIFLUX and PARTEK for inspection of ceramic or porous objects will be available from the engineers in attendance.

National Spectrographic Laboratories, Inc., and Jarrel-Ash Company
Booths 41, 42

Jarrell-Ash Company, manufacturers of the Wadsworth grating spectrograph, and National Spectrographic Laboratories, who maintain a large analytical service laboratory in Cleveland, Ohio, have combined to show a complete spectrographic installation consisting of a three-meter replica grating spectrograph, electric source unit, film processor, and microphotometer. They will also show metallurgical and stereoscopic microscopes of the latest design.

Tinius Olsen Testing Machine Co.
Booth 37

Selected machines will be shown in this booth from the wide range of testing equipment this company has available for investigating properties of all kinds of materials and products. A new torsion stiffness tester will be exhibited and a model of the company's new Electromatic (all electronic testing machine).

Parr Instrument Co.
Booth 12

Featured in this display will be the Parr self-sealing oxygen combustion bombs for calorimetry and for oxygen combustion reactions in chemical analysis, together with the Parr adiabatic oxygen bomb calorimeter for testing solid and liquid fuels. The several Parr sodium peroxide combustion bombs for chemical analysis will also be shown. Of special interest will be an exhibit of Parr apparatus for hydrogenation and other pressure reactions, including a new stirrer-type reaction unit for pressures up to 1000 psi. Parr engineers will be on hand to answer questions concerning the manufacture of special laboratory apparatus required for research programs involving high reaction pressures and high temperatures.

Phipps and Bird, Inc.
Booth 48

Phipps and Bird, Inc., of Richmond, Va., will exhibit the Christie Di-electric Desiccator, an instrument for determining moisture on flour, chemicals, coal, powdered food, cement, etc., in from ten to fifteen minutes without damage to the sample and without loss of water of crystallization. They will also display a new hammer mill designed especially for grinding fertilizer but well suited to the grinding of other materials. A long paper continuous feed kymograph will be shown; also a six-paddle flocculation water stirrer and other associated items.

Precision Scientific Co.
Booths 35, 36

This company will exhibit many new as well as standard items for scientific research and production control laboratories. Some of the newer equipment will be the Aniline Point Apparatus, Magnetic Stirrers, Motor-Matic Grease Worker, Percentrol Heaters, Recordomatic Titrator and others. Also on display will be equipment for the testing of cements, petroleum metals, rubber and plastics, and for general laboratory work.

Rainhart Co.
Booth 14

Moisture content, specific gravity, and other important physical data for most materials may be accurately determined within a few minutes, even in the field, with a new device to be featured in Booth 14 by Rainhart Co. Other soil, concrete, and general physical testing equipment designed and manufactured by them will also be on display. Their Engineering Manager will be available to discuss your special physical testing problems and equipment requirements with you.

Riehle Testing Machines Division American Machine and Metals, Inc.
Booths 30, 31

The exhibit of this company will feature the new PENDOMATIC Universal machine. Of particular interest is the new pendulum load indicator whereby change of scale ranges is accomplished by the turn of a range selector knob. This eliminates any possibility of error in weight combinations. There is no possibility of weights becoming mislaid or lost and the device facilitates the testing operations. Another item of interest is the new Snap-on Dial EXTENSOMETER. This eliminates the necessity for punch marking of the specimen. It is especially adaptable to thin sheets and small wires. The new Portable Hardness Tester of the Diamond indentor type will also be on display.

E. H. Sargent & Co.
Booths 62, 63

E. H. Sargent & Co. will display several pieces of laboratory equipment which should prove of interest to testing laboratory personnel. Among these instruments will be the latest model Sargent Potentiometric Visible Recording Polarograph, the Sargent Slomin Electrolytic Analyzer the Sargent Constant Temperature Bath line including the Hundredth Degree Bath, Quarter Degree Bath, and the Viscosimeter Bath. Also on display will be a newly designed and improved Cone Drive Stirring Motor. Daily demonstrations on the Polarograph will be given and technical personnel will be available for consultation.

Scott Testers, Inc.
Booth 55

Scott Testers, Inc., will display a Mooney Shearing Disc Viscometer equipped with entirely new automatic electronic recording. This equipment produces a reliable record of Viscosity and Scorch characteristics of rubber compounds, independently of operator or observer. One chart records Viscosity in Mooney Units, the other records directly temperatures from 100 to 400 F. Among other pieces of equipment will be the rubber industry's popular abrasion tester, the Scott-Dupont Abrader, which fulfills requirements as set forth in A.S.T.M. D394–47; also the Scott Torsion Tester with counter of 100,000 revolutions capacity, clamps rotating in opposite directions at 35 r.p.m., capacity to test up to 0.090 in. diameter music wire, initial tension of ½ to 17 lb. in units of ½ lb., with safety shields—mandrels supplied for preparing specimens 2 in., 4 in., or 8 in. long.

Illustrations of Typical Equipment to be Displayed in the 1948 A.S.T.M. Exhibit of Testing Apparatus and Related Equipment, Hotel Book-Cadillac, Detroit, June 21–25 incl.

←

Top Row, Left: A-C Bridge; Center: A New 36-Trace Recording Oscillograph for Direct and Multichannel Recording; Right: A Widely Used Hardness Testing Machine with a Variety of Scales for Different Materials.

Second Row, Left: Tube Furnace for Temperatures up to 2650 F.—this High-Temperature Laboratory Furnace is Ready for Operation When Plugged into the Electrical Circuit; Center: A New Physical Testing Machine of Modern Design, 5000 lb. capacity; Right: Oxygen Combustion Bomb.

Third Row, Left: One of a line of Indicating Viscometers, Compact and Convenient; Center: Cloud and Pour Testing Cabinet for Petroleum Tests; Right: Apparatus for Use in Specific Analysis Giving an Actual Determination of Spectrum Line Densities.

Bottom Row, Left: A Capacitance Bridge for Dielectric Measurements; Right: A New Instrument for Thickness Measurement.

Sperry Products, Inc.
Booth 26

Sperry Products will have on display the SR05 Supersonic Reflectoscope for the nondestructive testing of metals and other materials. A portable unit operating from 110-volt, 60-cycle power, the Reflectoscope uses high-frequency sound waves to locate defects up to a depth of 25 ft. Indication of a defect is given visually on an oscillograph screen so that location, depth, and size of the defect can all be determined accurately. The revolutionary "angle beam transmission" technique, recently announced, permits rapid and safe inspection of welds in shop or field. Also on display will be the Sperry Type SS01 Reflectogage, for measuring thickness of parts up to 4 in., particularly when access is only from one side, as with boilers, tanks, tubes, etc. A part of unknown thickness but known material is vibrated supersonically by the Reflectogage, and the frequency at which resonance is observed provides a method of determining thickness within 2 per cent accuracy. The instrument is also used for detection of laminar defects in thin materials, lack of bond, and bore eccentricity.

C. J. Tagliabue Corporation (N. J.)
Booth 61

The C. J. Tagliabue Corporation (N. J.) will display a comprehensive selection of the latest developments in the TAG line of industrial and laboratory testing instruments at the A.S.T.M. Exhibit. The presentation will include an interesting panel mounting a general assortment of laboratory and chemical thermometers and hydrometers. Additional items of interest will be found in the instruments for testing petroleum products of which TAG manufactures an extensive line. Among these will be shown the new TAG Colorimeter Stand with the TAG-Saybolt Chrometer, and the TAG-Saybolt Thermo Viscosimeter.

Waukesha Motor Co.
Booth 60

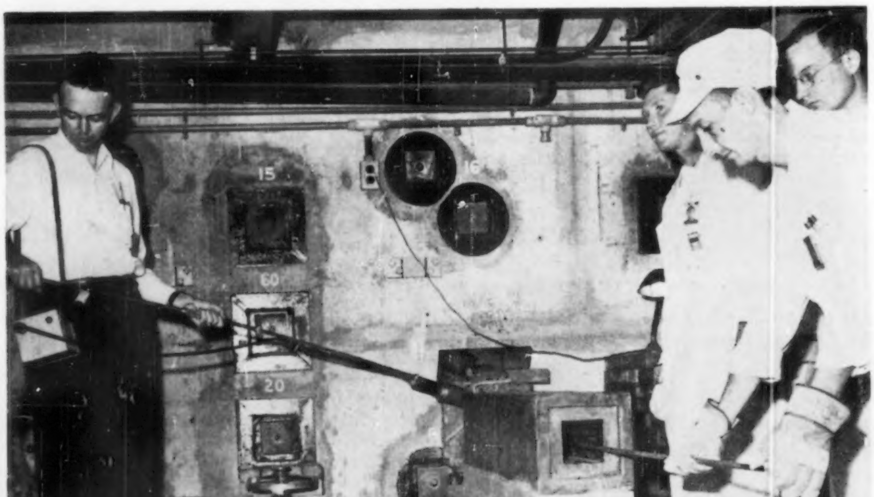
The display of this company at the A.S.T.M. Exhibit will consist of sample of their latest knock-test engine. The engine on display will be built upon the new design crankcase with rotary balancing system for low- or high-speed high-output service in line with the latest demands for Knock-Testing equipment. The crankcase can be furnished either with or without balancing system, or the balancing system can be added at a later date if desired. It is designed so that any of the standard A.S.T.M. cylinders can be used and all five test methods followed: (1) Motor Method (D 357 – 47); (2) Research Method (D 908 – 47T); (3) Aviation Method (D 614 – 47T); (4) Supercharge Method (D 909 – 47T); (5) Diesel Cetane Method (D 613 – 47T). In planning the new crankcase, the main structural parts are proportioned to the highest output of a piston type engine, with additional provision for receiving other cylinders with either push rod operated inclined valves or overhead camshaft valve gear. In addition to that the engine will have fully enclosed valves, and a Waukesha designed and built temperature control which is being shown for the first time.

Wilson Mechanical Instrument Co., Inc.
Booth 56

Shown in operation will be the latest models of the Normal "ROCKWELL" Hardness Tester and the "ROCKWELL" Superficial Tester. These new models include such improved features as totally enclosed dial gage, all controls grouped together and conveniently located beneath the capstan handwheel, and many important parts made from stainless steel. A full line of accessories will also be on display. In addition, the TUKON Tester will be exhibited. This will be the LR model which is a combination micro hardness tester and macro hardness tester. For micro hardness testing, the TUKON Tester is generally used with loads lighter than 3000 g. employing the Knoop indenter and the 136 deg. diamond pyramid indenter (commonly referred to as the Vickers test). For macro hardness testing, the TUKON Tester is used with the 136 deg. diamond pyramid indenter for loads up to 60 kg.

Late additions.—The Doble Engineering Company, Bellmont, Massachusetts will display in Booth 50 their testing equipment for evaluating various kinds of electric insulating materials. In Booth 11 the *Bowser Inc. Refrigeration Div.*, will show their cloud and pour point testing unit and the relative huminity simulation unit.

Operators Are Pulling an Isotope Stringer from the Pile. Health Physicist Is Monitoring the Job.



See pages 8 and 9 for information on Marburg Lecture

Preparing an Irradiated Unit for Shipment.

This Program is Subject to Change

All time indicated is Eastern Daylight Saving Time

Provisional Program

FIFTY-FIRST ANNUAL MEETING

of the

AMERICAN SOCIETY FOR TESTING MATERIALS

DETROIT, MICHIGAN **JUNE 21–25, 1948**

Committee Meetings held throughout the week at Book-Cadillac, Statler, and Detroit-Leland

	Morning	*Afternoon*	*Evening*
Monday, June 21	Committee Meetings	Committee Meetings Round-Table Discussion on Ultra-Sonic Testing—Committee E-7 (*Book-Cadillac*)	*1st* Symposium on Metallography in Color (Reports E-4 & E-7) (*Book-Cadillac*)
Tuesday, June 22	*2nd* Symposium on Usefulness and Limitations of Samples (Report E-11) (*Detroit-Leland*) *3rd* Symposium on Magnetic Testing (Report A-6) (*Book-Cadillac*)	*4th* Symposium on Magnetic Testing (Cont.) (*Book-Cadillac*) Movie on Modern Quality Control—4:30 P.M. (*Book-Cadillac*)	*5th* Symposium on Deformation of Metals as Related to Forming and Service (*Book-Cadillac*)
Wednesday, June 23	*6th* Session on Effect of Temperature on Properties of Metals (Report Jt. Effect of Temp.) (*Detroit-Leland*)	*7th* Session on Corrosion of Ferrous Metals (Reports A-5, A-10) (*Detroit-Leland*) *8th* Symposium on Tests for Ball Bearing Greases (Report D-2) (*Book-Cadillac*) *9th* Session on Waterproofing Brick, Masonry Materials (Reports C-2, C-7, C-8, C-12, C-14, C-15, C-18, D-8, D-18) (*Book-Cadillac*)	Annual Dinner and Dance President's Address (*Hotel Statler*)
Thursday, June 24	*10th* Session on Fatigue-Ferrous Metals; Paint (Reports D-1, A-1, A-3, A-7, A-9, E-9, Jt. Filler Metal) (*Detroit-Leland*) *11th* Symposium on Mineral Aggregates (Report D-4) (*Book-Cadillac*) *12th* Panel Discussion on Corrosion of Pressure Vessels (Report D-19) (*Book-Cadillac*)	*13th* Symposium on Speed of Testing (Reports D-13, E-1, E-8) (*Book-Cadillac*) *14th* Symposium on Procedures for Identifying Reactive Materials in Concrete, 3:30 P.M. (*Book-Cadillac*)	*15th* Marburg Lecture "Isotopes and Their Application in the Field of Industrial Materials," P. C. Aebersold Dudley Medal, Templin Award (*Rackham Memorial*)
Friday, June 25	*16th* Session on Fuels, Fire Tests, Bldg. Construction (Reports D-3, D-5, D-6, D-7, D-10, D-12, E-5, E-6) (*Book-Cadillac*) *17th* Session on Creep and Fatigue—Non-Ferrous (Reports B-1 to B-9, E-3) (*Detroit-Leland*)	*18th* Session on Cement, Concrete, and Concrete Aggregates (Reports C-1, C-9, C-11, C-16,) (*Detroit-Leland*) *19th* Session on Rubber, Plastics, Insulating Oil, Engine Antifreeze (Reports D-9, D-11, D-14, D-15, D-17, D-20) (*Book-Cadillac*)	

ROUND-TABLE DISCUSSION ON ULTRA-SONIC TESTING Monday, June 21, 2 P.M., **Book Cadillac**

Sponsored by Committee E-7 on Radiographic Testing this round-table discussion is open to all and it is expected that leading authorities in the field will participate.

Monday, June 21 8 p.m. First Session—*Book-Cadillac*

Symposium on Metallography in Color

Report of Committee E-4 on Metallography. L. L. Wyman, Chairman.

Report of Committee E-7 on Radiographic Testing. H. H. Lester, Chairman.

Symposium on Metallography in Color

This symposium is sponsored by Subcommittee IV on Photography of A.S.T.M. Committee E-4 on Metallography. It is the first time that the subject "Metallography in Color" has been discussed openly in this Society.

There have been numerous requests from those working in the field of metallography for the proper techniques to use to record in pictures the characteristic colors they see visually. Many laboratories are doing color work and some are turning out masterpieces but frequently at a high cost because they cannot predict results without making several trials under varying sets of conditions.

Like most all technical procedures, excellent color reproductions of microstructures can be had if a certain few basic conditions are adhered to. There are a few technologists working in metallography who have grown up with color and are quite proficient in this field. They have been asked to set down their procedures and show us how to make faithful pictures in color of microstructures.

The speakers will cover precautions necessary to take in specimen preparation, color of the illumination of the specimen, and the resulting color at the ground glass. Some will discuss their experiences in photographing nonmetallic inclusions, others the distinction by polarized light of inter-metallic compounds and delineation of the grains of alloys.

Microscope Optics for Color Metallography. James R. Benford, Bausch & Lomb Optical Co.

Metallographic microscopes have been rather consistently used with yellow-green filters in the light beam, and with green sensitive plates or film, so that color correction of the optics has been secondary to correction for other aberrations, notably flatness of field, astigmatism, and coma. With increasing interest in color metallography, the designer is led to reevaluate the optical combinations in so far as they are applied to color work. The experimental means used to evaluate optical designs, and the influence of color work on the design program, will be discussed.

Quality and Quantity of Illumination in Metallography. R. P. Loveland, Eastman Kodak Co.

Although color pictures must be quite accurately exposed, determination of the quantity of the illumination (illuminance) is relatively simple. The highest illumination in the plane is the best criterion for exposure and the easiest to determine. The reason for this criterion is explained and exposure constants given. Visual photometers can be satisfactorily used and have great sensitivity and range in spite of their relative cheapness. Photoelectric photometers have some advantage. The photographic method is ideal except for the time consumed. Directions for making suitable instruments of both types are given.

Analysis of the quality of illumination in the image plane is more difficult and takes somewhat more time. It can be very satisfactorily done, however, with a sensitive photocell photometer. On the other hand, it is only required for new optical arrangements if the light from the lamp is kept the same. This can be done easily as described. The illumination in the image plane is analyzed as ratios of readings through three special filters. A very straight-forward photometric method of determination of the correct compensating color filters is described.

Color Metallography Simplified. Mason Clogg, Jr., The American Rolling Mill Co.

A simplified method of making color photomicrographs is briefly discussed and illustrated. Heretofore the method of balancing the quality of light with liquid filters has been tedious and time consuming. This procedure has been greatly simplified with the aid of a color meter and a special set of glass filters. The only other variable in making color photomicrographs is exposure, since the film and color prints are processed by the manufacturer. This simplified procedure eliminates the need for a knowledge of the various color processes and processing equipment.

Some Applications of Color Metallography. W. D. Forgeng, Union Carbide and Carbon Research Laboratories, Inc.

Methods for obtaining color transparencies and color prints of metallographic specimens are briefly discussed. Many benefits can be gained by the judicious use of color micrography in the study of alloys.

Etching techniques have been developed that permit the identification of the various metallic constituents by characteristic staining. Details are given for the differentiation of the carbide phases in tool metals and the recognition of the sigma phase in iron-chromium base alloys by means of these techniques.

The use of reflected polarized light and crossed nicol prisms in combination with color micrography for distinguishing various intermetallic compounds and for delineating the grain size of alloys is discussed.

The Application of Color Photography to the Study of Nonmetallic Inclusions. A. M. Hall and E. E. Fletcher, Battelle Memorial Institute.

The various color phenomena which may be associated with nonmetallic inclusions in metals and alloys are described and their importance discussed. The manipulation with the microscope required to reproduce the inclusions' colors are then discussed. These comprise the characteristics of the light source and the optical system, the use of filters, and the determination of exposure time. A note on the processing of the film is also included. It was found that usually carbon-arc illumination filtered through an ultraviolet filter lightly tinted with blue, employed in conjunction with apochromatic optics, gave satisfactory results. Several illustrations of nonmetallic inclusions in color are furnished.

Tuesday, June 22 9:30 a.m. Second Session—*Detroit-Leland*

Held Simultaneously with the Third Session

Symposium on Usefulness and Limitations of Samples

Report of Committee E-11 on Quality Control of Materials. H. F. Dodge, Chairman.

Symposium on Usefulness and Limitations of Samples

Sampling and Its Uncertainties. S. S. Wilks, Princeton University.

This paper will deal with the principles of sampling with special reference to its use in engineering. Sampling fluctuations of means, sums, and percentages under conditions of random sampling and representative sampling will be discussed. The concepts of confidence limits and tolerance limits will be presented.

Variation in Materials, Testing, and Sample Sizes. Leslie E. Simon, Ballistic Research Laboratories.

The scientific sampling of materials is regarded as consisting of three essential parts: (*a*) Design of Experiment, (*b*) Execution of Tests, and (*c*) Interpretation of Results.

The Design of Experiment involves (1) careful identification of the test phenomena, (2) evidence of state of predictability in material sampled, and (3) a technical procedure designed to yield a maximum of information with a minimum of cost and effort.

The Execution phase must contemplate (1) the variability in the material and (2) precision and accuracy of measuring processes.

The Interpretation of Results should be recognized (1) as a predictive process, (2) as being sensitive to both the design of experiment and statistical control of its execution, and (3) as dependent upon an evaluation of these relations for a valid statement about the precision and accuracy of prediction.

In the Use of Quality Control little or no change need be made in usual terminology; the change consists of making use of probability information for calculated risks so as to minimize such costs as the cost of inspection plus the cost of consequences of accepting substandard materials, and so forth, thereby resulting in an important economy in over-all effort.

The Amount of Inspection as a Function of Control of Quality. G. R. Gause, Bell Telephone Laboratories, Inc.

A recent development in the field of quality control is the use of sampling procedures wherein the amount of inspection or sample sizes depend upon the extent to which quality of product is satisfactorily controlled. Under such procedures inspection results obtained on successive lots of product are summarized to obtain a measure of the general level of quality and its uniformity from lot to lot. Whenever such summaries indicate a satisfactory state of quality control, reductions in the amount of inspection are made. Various techniques for applying these principles are described and their applicability under different conditions discussed.

Tuesday, June 22   9:30 a.m.   Third Session—*Book-Cadillac*

Held Simultaneously with the Second Session

Symposium on Magnetic Testing

Report of Committee A-6 on Magnetic Properties. Thomas Spooner, Chairman.

Symposium on Magnetic Testing

The rapid development of new and superior magnetic materials in recent years has given rise to new and often difficult problems in connection with magnetic testing. Furthermore, there has been continued activity and development in the field of magnetic analysis by which the condition and quality of materials are determined from the results of nondestructive magnetic tests. It is the purpose of this symposium to indicate certain of the problems encountered in magnetic testing and to outline some of the methods that have been devised to overcome them. Recent developments in the field of magnetic analysis are also considered with special reference to their practical applications in the realm of nondestructive testing.

Testing Magnetic Materials. B. M. Smith, General Electric Co.

The article briefly describes some of the accepted methods and instruments commonly used by the Electrical Manufacturing Industry in the development, design, and control of magnetic materials. It includes a few practical considerations and precautions necessary in testing modern magnetic materials and puts special emphasis on the test limitations and difficulties of measurements to be encountered.

After outlining the magnetic properties to be covered and the quantities derived from them, the various methods under d-c. and a-c. classification of measurements are discussed. This discussion covers d-c. measurements in general, the ring method, the ballistic galvanometer, permeameter methods, types of permeameters, special measurements, and permanent magnet measurements and equipments. Under a-c. measurements a description is given of methods and equipments for measuring core loss, a-c. permeability, low induction tests, high-frequency measurements, and quality control.

Permanent Magnet Testing Methods and Their Validity in Determining Product Performance. C. A. Maynard and J. E. Mitch, The Indiana Steel Products Co.

Validity between product performance and test methods can be achieved by proper selection of test and correlation with performance. Factors involved in selection of test methods are discussed.

Permanent magnets are tested under working conditions which duplicate the working conditions of the magnet in the final product. Magnets are tested open circuited or under gap conditions in special fixtures whose permeance coefficients are adjusted to the magnet's lowest working point.

Test apparatus includes permeameters, galvanometers or fluxmeters, gauss meters, and magnetometers for determining magnetic properties of materials, flux in the magnet or a portion of the magnetic circuit, flux densities in a gap or leakage field, or comparative flux tests.

Core Loss Test for Narrow Silicon Steel Strip. J. A. Ashworth, Bell Telephone Laboratories, Inc.

When the width of cold-rolled silicon steel is too small to permit obtaining core loss, test strips at least $11^1/_{16}$ in. long, sheared crosswise of the grain, the standard practice is to check only the parallel grain loss. As is well known, the loss across the grain in this type of material is almost always considerably higher than that along the grain. This higher loss is of concern in the application of the material for laminations, the design of which is usually such that an appreciable fraction of the magnetic path lies crosswise of the grain. To meet the need for checking the cross grain loss on the narrower strip widths a test of the Epstein type, but employing strips as short as $3^1/_4$ in., has been devised. The width of the test strips is similar to that now in use in the standard A.S.T.M. method A34, that is $^{13}/_{16}$ in., and the total weight of sample is about 1 kg. The test core is assembled with butt joints at the corners. In this test the average of the losses crosswise and lengthwise of the grain may be determined directly, or by a slightly more involved procedure the loss corresponding to either direction may be deduced.

D-C Permeability Testing of Epstein Samples with Double-Lapped Joints. D. C. Dieterly, The American Rolling Mill Co.

Results are reported on a series of tests made to determine the correct magnetic path length when d-c. permeability tests are made on Epstein strips with double-lapped joints. Tests were made on identical materials with sample lengths of 53 cm., 28 cm., 15 cm., and 10 cm. in test frames designed for those samples. Materials so tested ranged from high-permeability oriented silicon steel to the lowest permeability materials normally encountered in commercial practice. From the results obtained it has been possible to determine the true magnetization curve (B *versus* H) of the materials with inductions ranging from 500 gausses to inductions corresponding to about 10 oersteds, as well as evaluating the magnetomotive force necessary to magnetize the double-lapped corners for each material.

Data are also presented from comparison tests made on 28 cm. polydirectional Epstein samples with double-lapped joints *versus* punched rings from (1) low-grade silicon steel, (2) hot-rolled transformer steel, (3) cold-rolled oriented silicon steel, and (4) high-permeability nickel alloy. Normal B *versus* H curves and hysteresis loops are shown for these materials.

Variation of Core Loss and Permeability of Electrical Grade Silicon Sheet Steel. A. C. Beiler and P. L. Schmidt, Westinghouse Electric Corp.

Statistical methods have been applied to the analysis of frequency distributions of core loss and permeability test values obtained from suppliers' reports of single tests on 11,000-lb. lots of electrical grade sheet steel over a considerable period of time. The same analysis has been applied to data obtained on 60 tests from each of several lots of electrical grade steel. The results indicate that the variability within a lot of material is substantially the same as the variability from lot to lot according to the single test. Results indicate further that the consumer is not sufficiently protected against the receipt of material which does not meet the minimum permeability requirement at 16 kilogausses or the maximum core loss guarantee at 10 kilogausses.

Tuesday, June 22   2:00 p.m.   Fourth Session—*Book-Cadillac*

Symposium on Magnetic Testing (*Continued*)

The Evaluation of Hysteresis Core Loss by Power Equations. Horatio W. Lamson, General Radio Co.

Basic theory stipulates that the component of core loss which is due to eddy currents should be proportional to the square of the induction present. The manner in which the hysteresis component of core loss depends upon the degree of magnetization is not so readily defined. Steinmetz has proposed the equation:

$$W_h = \eta B^\epsilon$$

to evaluate the hysteresis loss in cgs. units. A typical value of 1.6 has been used for the exponent in conjunction with coefficient values depending upon the material used. However, when the logarithm of the energy is plotted against the logarithm of the induction, a nonlinear graph results which, when analyzed, shows that both ϵ and η are not constants but vary considerably with B, especially at higher induction values.

The author considers also the companion equation:

$$W_h = \alpha H^\gamma$$

evaluating core loss in terms of the applied magnetizing force and verified Rayleigh's predicted value of 3 for γ at initial permeability. Using the same empirical data, it is found that the exponent γ and the coefficient α are subject to quite different variations over the range of H corresponding to the induction values employed in the Steinmetz equation.

The paper gives a detailed analysis of these two equations using data obtained with small toroidal cores constructed of five different ferro-magnetic alloys developed for use in transformers.

Magnetic Analysis Inspection in the Steel Industry. Theodore Zuschlag, Magnetic Analysis Corp.

The subject paper deals with magnetic instrument testing as used for the production inspection of steel products and, more particularly, relates to modern applications of Magnetic Analysis Inspection in the steel industry.

Following a short discussion of the physical laws and technical requirements involved late types of Magnetic Analysis Inspection methods, apparatus and equipments are described with emphasis laid on the more practical points of design and application. Finally, the solution of various industrial test problems by means of these equipments is discussed with special regard to the technological and commercial aspects of the instrument method of nondestructive Magnetic Analysis Inspection.

Magnetic Stress Analysis. P. E. Cavanagh and T. Wlodek, Ontario Research Foundation.

Developments in the use of magnetic analysis methods for comparison and measurement of internal stresses in metals indicate further practical applications of such tests.

Recent improvements in instruments suitable for this work are discussed and the limitations of the methods when applied in production are brought forth.

In the more exact field of stress analysis by magnetic means numerical values for internal stresses may be obtained by simple mathematical relationships between stress and magnetic properties when specified procedures are followed as outlined in this paper.

Methods of performing such tests are described and the fundamental relationships between stress and magnetization presented in convenient form.

The Testing of Magnetic Recording Media. D. E. Wiegand, Armour Research Foundation, University of Illinois.

Three types of measurement are used at the Armour Research Foundation in evaluating experimental magnetic recording media. These are listening tests, measurements of final performance characteristics, and basic magnetic measurements. Listening tests are performed on conventional magnetic recording apparatus. Several sources of program material are provided. Final performance measurements are made on a special tester. A large variety of tests such as frequency-response, maximum signal level, noise level, and so forth are performed on this apparatus, and convenient means are provided for changing from one test to another. Basic magnetic measurements are made on a cathode-ray hysteresis loop tracer powered at sixty cycles. Built-in calibration and positive means of compensation incorporated in this tester allow an accuracy of measurement comparable to that of the ballistic galvanometer method, with great savings in time required for the measurements. Correlations have been found between basic properties and final performance characteristics of recorder media. These correlations make possible the comparison of medial largely on the basis of their basic magnetic properties and serve as a valuable guide in the development of improved media.

PAPERS ON SOILS FOR ENGINEERING PURPOSES—Tuesday, June 22, 3.00 p.m. Book-Cadillac

As a feature of the meeting of Committee D-18 technical papers are being prepared for presentation following the business meeting. Two papers have already been offered and several others are expected. Those already listed are:

The Importance of Relative Density in Studying the Behavior and Characteristics of Soils. D. M. Burmister, Columbia University.

The Determination of Limits for the Control of Placement Moisture in High Rolled Earth Dams. W. G. Holtz, Bureau of Reclamation.

All those interested in these papers are cordially invited to attend.

MOVIE AND TALK ON MODERN QUALITY CONTROL—Tuesday, June 22, 4.30 p.m. Book-Cadillac

Described in a Talk by Simon Collier, Johns Manville Corp.

During the war years, the necessity of using many substitutes tended toward a lowering in quality standards and as a result customers are now most critical and are demanding more quality than is really necessary. Industry is currently faced with this problem and it behooves them to recognize this situation and take corrective steps.

Johns-Manville is fully aware of this situation and has taken definite action. They have instituted an extensive training program designed to teach the most modern techniques of Quality Control to their Production and Inspection personnel. A part of the training program is a sound color film outlining the basic principles of Statistical Quality Control. This film was undertaken because of the past success in training employees by means of audio-visual devices.

It should be stressed that no Quality Control program can succeed without proper planning and selling the program to the production and engineering groups.

Tuesday, June 22 8.00 p.m. Fifth Session—*Book-Cadillac*

Symposium on Deformation of Metals as Related to Forming and Service

The last few years have witnessed a rapidly accelerating rate of accomplishment in the approaches to a more rational and fundamental concept of metal flow and fracture. These approaches vary from the more academic hypothesis and theories of the physical metallurgist and physicist to those of the works metallurgist in his laboratory and plant.

Because of these efforts, it has come to be recognized that such formerly abstract terms as bi-axial and tri-axial stresses, balanced and unbalanced stress patterns, deformation rates, and similar factors are really the controlling variables in the fabrication, application and failure of metallic materials.

Cognizance of these factors have fostered critical surveys of metal fabrication and failure, with the result that a number of new methods of test have been devised which accomplish two things of basic import: First, they closely simulate actual service conditions as these factors are analyzed in terms of present knowledge; and, secondly, they provide the proving ground between the theory and practice in our more intelligent applications of metals for structural uses.

Measurement of Ductility in Sheet Metals. John R. Low, Jr., and Thomas A. Prater, The Pennsylvania State College.

Methods developed for the measurement of uniform elongation and the reduction in area in modified tension type tests of sheet metals are described. The relationship between these two measures of ductility and forming limits in various types of forming operations, particularly stretching and bending, is discussed. Data are presented illustrating the influence of specimen dimensions and lateral restraint due to gripping, on elongation measurements for various gage lengths.

Tests of Ductility in Ship Structure. W. P. Roop, Swarthmore College.

Some recent studies relating to steel ships are analyzed from the point of view of simulated service testing. Special attention is given to work on wide flat plates which may be considered to represent deck plating, and to differ from that in an actual ship mainly in the dimension of width.

The problem of service fracture in ships is not solved by changes in the material alone, especially without a quantitative evaluation of the benefit obtained. This evaluation can ultimately be made only on an extended structure; data from small specimens of the metal are valid only if correlation with the metal as it works in the structure is assured.

Notch-Sensitivity in Ship-Plate Correlation of Laboratory Scale Tests with Large Scale Plate Tests. Noah Kahn and E. A. Imbembo, Brooklyn Navy Yard.

During the early part of World War II, a considerable number of welded merchant vessels developed serious fractures in the hull plating which, in many instances, occurred with explosive suddenness. Particularly bewildering phenomena in these casualties were the appearance and nature of the fractures; these exhibited a degree of brittleness not ordinarily associated with the behavior of a normally ductile material such as medium steel ship plate. This paper discusses various laboratory-scale test methods used in evaluating the susceptibility of ship plate to brittle or cleavage fracture and their correlation with large-scale internally notched plate tests.

Hydraulic Bulge Testing of Sheet Metals. W. Lankford, Carnegie-Illinois Steel Corp.

Information derived from a simple tension test, in which a sheet specimen is stretched in only one direction, may not be directly applicable to the more complex stretching conditions encountered in practical forming operations. The hydraulic bulge test, which permits the stretching of sheet specimens in more than one direction, is described in this paper. The circular bulge test, which has been used in a limited sense previously, has been studied further in order that more fundamental information can be obtained. In addition, an elliptical bulge test has been developed in which the specimen is stretched more in one direction than in the other, in contrast to the circular test in which the stretch is uniform in all directions.

Notch Bar Tension Tests on Annealed Carbon Steel Specimens of Various Sizes and Contours. G. Sachs and M. L. Fried, Case Institute of Technology.

Wednesday, June 23 10.00 a.m. Sixth Session—*Detroit-Leland*

Session on Effect of Temperature on Properties of Metals

Joint Committee on Effect of Temperature on the Properties of Metals. N. L. Mochel, Chairman.

Appendices:

Studies on Graphitization Susceptibility of Carbon-Molybdenum and Chromium-Molybdenum Steels. J. J. Kanter and E. A. Sticha, Crane Co.

Results of graphitization susceptibility tests on carbon- and chromium-molybdenum casting steels after 2 years aging at 1025 F. generally confirm trends indicated at the time of the last report. Effectiveness of the ½ of one per cent chromium addition in retarding, although not preventing, graphite formation has been further substantiated. Graphite has been observed in one of the carbon-molybdenum steels deoxidized with silicon only. More highly alloyed compositions, namely grades WC 4 and WC 6 of A 217 and grade C3A of A 157, have developed no graphite in 10,000 hr. aging at 1100 F. The study on A 280 chromium-molybdenum steel pipe has been under way for 13,000 hr. and no graphite has been noted.

High-Temperature Bolting Materials. Ernest L. Robinson, General Electric Co.

This is the Second Progress Report prepared by the contributors to Project 16 of the A.S.M.E.-A.S.T.M. Joint Committee on the Effect of Temperature on the Properties of Metals. The First Progress Report of Project 16 published in 1939 discussed "The Resistance to Relaxation of Materials at High Temperature" and showed how high temperature bolts gradually relax over a period of time and outlined a simple manner of evaluation whereby bolts may be designed to hold joints tight. This Second Progress Report gathers together data on bolting materials for temperatures up to 1000 and 1500 F. made available by 13 different contributing organizations.

High-Temperature Properties of Rotar Disks for Gas Turbines as Affected by Variables in Processing. H. C. Cross, and Ward F. Simmons, Battelle Memorial Inst.; J. W. Freeman, and E. E. Reynolds, University of Michigan.

The room-temperature and high-temperature (1200–1500 F.) properties of seven heat-resisting alloys fabricated in the form of large forged disks (some as large as 21-in. diameter, 3-in. thick) are discussed. The effects of fabricating procedures, heat treatment, and location in the disks on the structure, and on the tensile, impact, rupture, and creep properties are discussed.

Fatigue and Static Load Tests of an Austenitic Cast Iron at Elevated Temperatures. W. Leighton Collins, University of Illinois.

In the 1941 Proceedings of the A.S.T.M. there is a paper entitled "Fatigue and Static Load Tests of a High-Strength Cast Iron at Elevated Temperatures" by the writer and James O. Smith. After publication, suggestions were made that the work be extended to include an iron designed for use at high temperatures.

Material was then obtained through the courtesy of the International Nickel Company, and specimens were prepared. Actual testing was interrupted by the war and then, in order to complete the work, funds were made available by the A.S.T.M. (through Subcommittee XXII of A-3) to aid in the completion of the work. The proposed paper will closely parallel the older presentation.

An Experimental Study of the Influence of Various Factors on the Mode of Fracture of Metals. Paul G. Jones and W. J. Worley, University of Illinois.

The factors related to the external conditions imposed on a given metal which determine whether the mode of fracture be a ductile type of fracture or a brittle type of fracture are considered to be rate of strain, stress concentration, state of stress, and temperature. The paper presents experimental results on the influence of combinations of these factors on the mode of fracture of three steels and an aluminum alloy. The effect of strain aging on the mode of fracture of a semikilled steel and a rimmed steel was also investigated.

The stress concentration and state of stress were varied by making tests on notched and unnotched specimens in tension and on unnotched specimens in torsion. The rate of strain was varied by making static and impact tests in tension and in torsion. Test temperatures from room temperature to −310 F. were used in determining the temperature of transition from a ductile to a brittle type of fracture.

Wednesday, June 23 2.00 p.m. Seventh Session—*Detroit-Leland*

Held Simultaneously with the Eighth and Ninth Sessions

Session on Corrosion of Ferrous Metals

Report of Committee A-5 on Corrosion of Iron and Steel. T. R. Galloway, Chairman.

Report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys. Jerome Strauss, Chairman.

Quantitative Evaluation of Corrosive Conditions. W. F. Bonwitt and I. Eisen, Burndy Engineering Co.

Published in ASTM BULLETIN, No. 151, March, 1948, p. 84.

Factors of Importance in the Atmospheric Corrosion Testing of Low Alloy Steels. H. R. Copson, The International Nickel Co., Inc.

Five-year results on 71 low-alloy steels in marine and industrial atmospheres are used to show that the results obtained depend on the location (whether industrial, marine, or rural), on the duration of the tests (the benefit of alloying increases with time), on the manner of exposure (particularly whether sheltered or boldly exposed), on the method of estimating corrosion (whether weight loss, pit depth, or time to disintegration), and on the weather (particularly as regards wetness and pollution). Under all conditions alloying seems of value, but the magnitude of the benefit, and the relative merit of different steels and alloying elements varies.

Laboratory Corrosion Tests of Iron and Steel Pipes. George A. Ellinger, Sybil B. Marzolf, National Bureau of Standards; and Leo J. Waldron, Naval Research Laboratory.

Continuous flow laboratory corrosion tests of ten types of uncoated ferrous pipes were made over periods of time extending up to ten years. The corroding medium was Washington, D. C., tap water continuously circulated through columns of the test samples. Corrosion was measured as loss of weight and depth of pits in relation to the time of exposure. While most of the pipes corroded at somewhat similar rates there were small but practical differences in the corrosion of some of the materials.

An Investigation of the Possibilities of Organic Coatings for the Prevention of Corrosion Fatigue Failures in Steel. Robert C. McMaster, Battelle Memorial Institute.

R. R. Moore rotating beam fatigue tests were made of bare specimens of S.A.E. 1045 Steel operating in air and in a corrosive brine (NaCl) and of similar specimens with intact and with scratched organic coatings. The endurance limit of the steel under reversed bending in air in the absence of corrosion was about 48,000 psi. Typical four-layer baked organic coatings increased the operating life in corrosive brines at 40,000 psi. fully reversed maximum stress from 430,000 cycles (bare) to more than 64,000,000 cycles (coated). A five-layer system of air-drying materials increased the operating life under the same test conditions to more than 37,000,000 cycles. However, after failure of the organic coating (simulated by scratches cut through the coatings) the remaining operating life time was found to be about the same as that of new bare specimens.

Atmospheric Durability of Steel Containing Nickel and Copper—Additional Exposure Data. N. B. Pilling and W. A. Wesley, The International Nickel Co., Inc.

Four of the series of weathering tests described in the original report in 1940 have been continued, the oldest now being in its twenty-third year. One set involves large sheets fabricated to simulate roofing sections. Here the advantage of nickel-copper steels over copper steels becomes more impressive with time. Another group includes 170 different experimental steels representing various combinations of nickel, copper, manganese, silicon, carbon, and phosphorus contents. The beneficial effects of nickel increase with nickel content but the optimum addition of copper to nickel steels is in the neighborhood of one per cent. Phosphorus and silicon additions enhance the weathering resistance of nickel-copper steels.

Wednesday, June 23 2.00 p.m. Eighth Session—*Book-Cadillac*

Held Simultaneously with the Seventh and Ninth Sessions

Symposium on Functional Tests for Ball Bearing Greases

Report of Committee D-2 on Petroleum Products and Lubricants. C. Dantsizen, Chairman.

Bearing Corrosion Tests Using the MacCoull Tester and a Study of the Kinetics of Oil Oxidation. Hugh R. Lehman, U. S. Army Air Force and L. Kermit Herndon, The Ohio State University.

A method of graphical analysis for the corrosion curves exhibited by the MacCoull Bearing Corrosion Tester is presented. Use of this method produces a specific reaction velocity constant. This constant obeys the classical Arrhenius equation relating the reaction velocity constant with temperature. The experimental energy of activation and the probability factor for lubricating oils was calculated by application of the Arrhenius equation. It is suggested that these constants will express the tendency of a lubricating oil to promote bearing corrosion.

Application of this method to such widely differing test methods as the Indiana Stirring Oxidation Test and the Oxygen Absorption Method of Dornte is demonstrated. This extension suggests that a method of correlating the many bearing corrosion and oil oxidation tests now exists.

Symposium on Functional Tests for Ball-Bearing Greases

The soundness of the principle of performance evaluation of greases has been generally accepted but agreement on procedures for such evaluation has not yet been reached. In an effort to standardize such tests for ball-bearing greases, a committee of the Society has found a variety of methods from which to choose. To aid their selection, this symposium has been arranged so that users of several methods can describe the degree of their successes.

The authors represent a variety of interests in the subject. One paper is from a grease manufacturer; one, from a machinery manufacturer; a third, from a company using grease only for lubrication of its production machinery; another, from an association of manufacturers interested in lubrication of their product; and the last, from a consumer which manufactures none of its machinery but needs to lubricate it. From these diverse attacks on the problem and the discussion of the progress made by each, it is hoped to derive information which will lead to enlightened standardization of functional tests for ball-bearing greases.

Development of Functional Grease Methods for the Aircraft Industry. D. H. Moreton, Douglas Aircraft Corp.

This paper will present in survey form the work of S.A.E. Committee S-5c to date in attempting to develop a series of qualitative functional grease tests for the evaluation of commercial aircraft greases.

There is much evidence to show that existing grease tests are generally unreliable in attempting to predict performance in many aircraft mechanisms. Work to date has indicated that many existing tests with small modifications show much promise of bridging this gap. Other proprietary test methods developed by the aircraft companies and petroleum research labs working with the aircraft companies are also being investigated.

Evaluation of the test methods is largely on the basis of performance of a number of greases known to have certain functional characteristics in aircraft service during the last several years.

The work of the committee is not complete, but the paper will present the approach that is being used as well as some of the results so far available. The paper will be prepared in sections by each man responsible for a certain phase of the program and will be abstracted for presentation by the author.

Grease—An Oil Storehouse for Bearings. D. F. Wilcock and Marshall Anderson, General Electric Co.

This paper presents a long-range program of study of the lubrication of ball bearings. A four-bearing testing machine or original design and other equipment developed for this program are described, and the results of a series of life tests under controlled conditions are reported. The data provide a basis for a fundamental, quantitative theory of ball-bearing lubrication that is outlined in the paper. One important conclusion is that the role of the grease in a grease lubricated bearing is to act as a sponge that will release oil at a very slow, controlled rate. The implications of this conclusion on the design of bearing installations and the selection of greases are also explained.

Laboratory Performance Tests for Anti-Friction Bearing Greases. M. Herbst, W. A. Prendergast, R. S. Barnett, W. J. Finn, and O. P. Puryear, The Texas Company.

Seven machines for evaluating ball- and roller-bearing greases are described. For example, two of the machines are short-time screening tests which evaluate grease texture and adhesiveness and leakage tendencies; whereas two other machines represent endurance tests which given an evaluation of lubrication, one of them being heavily loaded. Data are given on a number of types of greases, and some correlation of the laboratory tests with field service has been possible.

Service Experience with Grease. C. L. Pope and W. T. Everitt, Eastman Kodak Co.

The testing of ball-bearing and industrial greases in operating equipment is described. Analysis of the conditions to be met by the greases together with the results of many tests are given. Such physical data on the greases tested as are usually available to the user is presented. The difficulty of running full scale tests and evaluating results in a variety of operating conditions becomes evident in the development of the paper. It is the purpose of this paper to indicate the need for the development of functional tests or the correlation of existing functional tests to grease lubrication.

Factors Affecting Simulated Service Tests of Greases. Sidney M. Collegeman and John R. Belt, U. S. Naval Engineering Experiment Station.

A high-speed high-temperature grease testing apparatus known as the Universal Grease tester is described. The effect of various test conditions on the results are shown. Paired results under the various conditions: 300 *versus* 325 F., 250 F. *versus* 300 F., precision-grade *versus* standard-grade ball bearings, 3-lb. *versus* 50-lb. radial load: are compared. Of the three variables studied only temperature is shown to have a definite effect on the length of the tests. The use of radial loading as an accelerating agent is shown to be of little value at the loads used. The use of precision grade bearings in place of standard grade bearings was not found to improve the reproducibility of the test. The use of heat stabilized ball bearings is indicated.

Wednesday, June 23 2.00 p.m. Ninth Session—*Book-Cadillac*

Held Simultaneously with the Seventh and Eighth Sessions

Session on Waterproofing, Brick, Masonry Materials

Report of Committee D-18 on Soils for Engineering Purposes. E. J. Kilcawley, Chairman.

Report of Committee D-8 on Bituminous Waterproofing and Roofing Materials. J. S. Miller, Chairman.

Testing Surface Waterproofers. F. O. Anderegg, John B. Pierce Foundation.

Methods for testing surface waterproofers have been developed which involve the coating on one flat side and four edges of a suitable common brick with the waterproofer and testing rate of absorption, rate of transpiration, resistance to efflorescent crystal pressure, first without and then in combination with freezing.

The treated bricks are also exposed to the weather over winter. The laboratory findings have been checked by applying the treatments to cinder block piers and to leaking cellar walls. Such walls can be treated to prevent egress of liquid moisture without too serious an effect on the transpiration rate.

Outside walls may be treated to reduce the rate of water ingress, but since it is felt that their transpiration should not be too seriously interferred with, some doubt arises as to how tight they should be made.

Report of Committee C-2 on Magnesium Oxychloride Cements. L. S. Wells, Chairman.

New Type Weighted Needles for Determining the Setting Times of Magnesium Oxychloride Cements. Harry E. Chisholm, Westvaco Chlorine Products Corp.

A new type weighted needle has been developed for use in determining the initial and final setting times of magnesium oxychloride cements. The initial setting time needle weighs 1 lb and carries a 0.167-in. diameter tip which projects 0.015 in. beyond a 0.250-in. diameter shoulder. The final setting time needle weighs 4 lb. and carries an 0.083-in. diameter tip which projects 0.015 in. beyond a 0.167-in. diameter shoulder. The tip and the shoulder are concentric. The planes of the end of the tip and the shoulder are perpendicular to the axis of the needle shaft. The shoulder feature serves as an integral depth gage and the initial and final setting times, respectively, are taken to be the age at which the depths of needle marks made at equal time intervals are such that the shoulder first fails to make an impression on the surface of the oxychloride cement test specimen. These needles give average setting time values which are comparable to those obtained with Gillmore needles but with standard deviations which are one-third to two-thirds of those of the Gillmore needles.

Report of Committee C-7 on Lime. W. C. Voss, Chairman.

Report of Committee C-8 on Refractories. J. D. Sullivan, Chairman.

Report of Committee C-12 on Mortars for Unit Masonry. Theodore I. Coe, Chairman

Report of Committee C-14 on Glass and Glass Products. Louis Navias, Chairman.

Report of Committee C-15 on Manufactured Masonry Units. D. E. Parson, Chairman.

Report of Committee C-18 on Natural Building Stones. Oliver Bowles, Chairman.

Factors in the Resistance of Brick Masonry Walls to Moisture Penetration. C. C. Connor, New Jersey Bell Telephone Co.

This study covers one hundred building units which have been exposed for long periods to the storms of a seaboard area. The factors which combined to produce moisture-proof walls above grade, and those which apparently caused leaks, are identified. The construction varied widely, and the influences of a number of masonry materials and practices are evaluated. The investigation shows that a certain combination of factors was required to consistently produce moistureproof walls. A report is made on forty-two buildings of the group where moisture penetration of the brick walls was prevented by the use of materials and practices selected on the basis of the best available information from the laboratory and the field.

Expansive Characteristics of Hydrated Limes and the Development of an Autoclave Test for Soundness. Lansing S. Wells, W. F. Clarke, and Ernest M. Levin, National Bureau of Standards.

A technique for preparing, curing, and autoclaving 1-by 1- by 10-in. cement-lime bars was developed and the expansive characteristics of eighty commercial hydrated limes were determined. On the basis of chemical analysis and percentage of unhydrated oxide, the hydrated limes were classified into four series: high-calcium, regularly hydrated dolomitic, highly hydrated dolomitic, and magnesium. Data on the expansions of cement-lime bars prepared in the proportions of 2 parts cement to 1 part lime, 1 part cement to 1 part lime, and 1 part cement to 2 parts lime, by weight, and autoclaved to 295 psi. gage pressure for 3 hr., showed that bars prepared with the regularly hydrated dolomitic limes, which had the highest percentages of unhydrated oxides, also had the highest percentages of expansion. The high-calcium limes characterized, in general, by the lowest percentages of unhydrated oxides, gave the lowest percentage of expansion. From criteria set forth for a procedure for determining the soundness of hydrated limes, a test is proposed with a suggested limit of expansion of 1.0 per cent

PAPERS ON PAINT—Wednesday, June 23 3.00 p.m. Book-Cadillac

After the business meeting of Committee D-1 on Paint, Varnish, Lacquer and Related Products, a group of technical papers will be presented. All those interested in these papers are cordially invited to attend.

Wednesday, June 23 6.30 p.m. *Hotel Statler*

Dinner and Dance

Annual Dinner

President's Address

Dance

The Detroit Council through its general committee on arrangements has scheduled a Dinner and Dance to be held on Wednesday evening as a feature of the Fifty-first Annual Meeting. At the Dinner the retiring president, Mr. T. A. Boyd, General Motors Corp., will give his presidental address.

Thursday, June 24 9.30 a.m. Tenth Session—*Detroit-Leland*

Held Simultaneously with the Eleventh and Twelfth Sessions

Session on Fatigue—Ferrous Metals; Paint

Report of Committee D-1 on Paint, Varnish, Lacquer, and Related Products. W. T. Pearce, Chairman.

Report of Committee E-9 on Fatigue. R. E. Peterson, Chairman.

Report of Committee A-1 on Steel. N. L. Mochel, Chairman.

Report of Joint Committee on Filler Metal. J. H. Deppeler, Chairman.

Some Aspects of the Effect of Metallurgical Structure on Fatigue Strength and Notch-Sensitivity of Steel. T. J. Dolan and C. S. Yen, University of Illinois.

It was the purpose of this investigation to determine the extent to which certain changes in metallurgical structure (produced by different heat treatments) affected the fatigue strength and notch-sensitivity of several steels, and to ascertain whether the types of metallurgical constituents that improve localized toughness in a Charpy impact test also prove beneficial in fatigue. Experimental data are presented from static, fatigue, and impact tests, on two alloy steels and one carbon steel, quenched and tempered to approximately the same hardness level. Duplicate tests were made for each steel in a drastically quenched-and-tempered condition, and for a slowly quenched-and-tempered condition.

In general, the steels rapidly cooled in quenching exhibited higher yield ratios, slightly higher endurance limits, and less notch-sensitivity in fatigue than the same steels slowly quenched and tempered. The fatigue strength of tempered martensitic specimens with a 60 deg. V-notch, ranged from 11 to 44 per cent higher than for the same metals heat treated to a structure of pearlite plus ferrite (but having the same hardness and tensile strength).

Changes Found on Run-In and Scuffed Surfaces of Steel, Chrome Plate, and Cast Iron. J. N. Good and Douglas Godfrey, National Advisory Committee for Aeronautics.

Report of Committee A-3 on Cast Iron. J. T. MacKenzie, Chairman

Report of Committee A-7 on Malleable-Iron Castings. W. A. Kennedy, Chairman.

Some Characteristics of Residual Stress Fields During Dynamic Stressing Above the Endurance Limit. James B. Duke, Hamilton Standards Development Division of United Aircraft Corp.

A qualitative experimental investigation of the magnetic properties of ferromagnetic materials undergoing reversed flexural stress is described with applications in the prediction of fatigue failure and the direction and magnitude of internal stress fields. The development of a partial theory based on the classical magnetic domain concepts forms an important portion of the paper.

The experimental technique utilizes readily available commercial equipment and a discussion is given on the possible industrial applications. Important verification by an independent fatigue failure check shows that the theory and method described may be used in a wide variety of metallurgical investigations on the fatigue properties of materials, and that it can be extended to nonferrous alloys.

Report of Committee A-9 on Ferro-Alloys. W. C. Bowden, Jr., Chairman.

The Effect of Fatigue on Tension-Impact Resistance. William H. Hoppmann II, The Johns Hopkins University.

The purpose of this paper is to indicate the possibility of using the high-velocity tension-impact test to determine the loss of impact resistance caused by fatigue in metals.

Tension specimens were cut from a low-carbon steel plate in a known fatigue condition and subjected to impact tests at various velocities up to 120 ft. per sec.

Energy and total elongation as functions of impact velocity are given in the form of graphs. The data show that the tension-impact test at moderately high velocities may have considerable value in studies of fatigue damage to structures in service.

An Hypothesis for the Determination of Accumulative Damage in Fatigue. F. E. Richarts Jr. and N. M. Newmark, University of Illinois.

Thursday, June 24 9.30 a.m. Eleventh Session—*Book-Cadillac*

Held Simultaneously with the Tenth and Twelfth Sessions

Symposium on Mineral Aggregates

Report of Committee D-4 on Road and Paving Materials. W. J. Emmons, Chairman.

Symposium on Mineral Aggregates

The enormous demand since the war for mineral aggregates as a material of construction has focused the attention of many on the need for complete and up-to-date general knowledge of the characteristics and uses of this material. In this way more intelligent and economical usage can be made of it. The original symposium on mineral aggregates, presented in 1929, filled such a need at that time. However, sufficient time has elapsed to warrant the presentation of a new symposium on this subject in which the purpose of each paper will be to give the present-day picture of each particular phase that it covers, especially to point out the development that has taken place since the presentation of the original symposium almost twenty years ago.

The coverage of the particular subject assigned to each contributor, whether the subject is restricted or comprehensive, is broad and not confined to the local area or local connections with which he might be most familiar. Finally, the papers in this symposium are written primarily for that group of individuals interested in the characteristics and uses of mineral aggregates who normally are not intimately connected with aspects of research and testing.

Distribution of Mineral Aggregates. K. B. Woods, Purdue University.

This paper summarizes some of the information available covering the distribution of mineral aggregates. The origin of aggregates is discussed on the basis of the method of occurrence, that is, glacial or water-deposited granular materials such as naturally occurring sands and gravels, and igneous, metamorphic, or sedimentary rock as regard solid-rock materials.

Petrographic and Mineralogic Characteristics of Aggregates. Roger Rhoades and Richard C. Mielenz, Bureau of Reclamation.

The petrographic and mineralogic characteristics and geologic history of rock formations and sand and gravel deposits determine the composition, gradation, and quality of aggregates. Thus, because of their several modes of occurrence, igneous, sedimentary, and metamorphic rock formations present different problems to the quarryman and produce aggregates of differing serviceability.

The physical and chemical properties of aggregate particles are described and discussed. Because these properties arise from the mineralogic composition and internal texture and structure of the particles, they can evaluated by petrographic methods. The interrelation of petrographic character and serviceability of concrete aggregate is demonstrated by several case histories.

Physical and Chemical Tests and Their Significance. Harold S. Sweet, Joint Highway Research Project, Purdue University.

This paper consists essentially of a review of the important literature pertaining to the subject and the compilation of a selected bibliography. The development of aggregate test techniques is traced and their applicability to present-day aggregate usage is discussed.

The techniques which have been used in research on aggregate properties are also described. These include the common mineralogical identification tests, the determination of volume change, elastic properties, porosity, reactivity with alkalies, and simulated service tests such as stripping of bituminous films and accelerated weathering of concrete. Although most commonly used for obtaining design information, the specific gravity and absorption tests are included in this section.

Sieve analysis and gradation have not been considered since they are covered in another paper of this symposium.

Sampling of Mineral Aggregates. C. E. Proudley, North Carolina State Highway and Public Works Commission.

Methods for securing representative samples of mineral aggregates under various conditions from the time that processing begins until the aggregate is used in the work are discussed, pointing out the probable sources of error and suggesting means for minimizing these errors. The purposes for which samples are taken and the factors which have an influence on size of samples and frequency of sampling are considered. The importance of assigning an inspector to the task of sampling who has adequate knowledge of production of aggregates, testing, and the use of aggregates in construction is emphasized.

Production and Manufacture of Fine and Coarse Aggregates. Nathan C. Rockwood, *Rock Products*, Maclean-Hunter Publishing Corp.

The processing of natural and manufactured aggregates is described briefly, including exploration to determine the planning of excavation and transportation methods adapted to local conditions; successive steps in processing—cleaning, washing, crushing, screening or sizing, hydraulic classifying, air separation, fine reduction, special processing to remove "soft" particles, flats, etc., storage in bins and stockpiles, recovery from storage and shipping facilities. Manufacture of slag, burned-clay and lightweight aggregates is described briefly. Plant testing and administrative details of commercial operations are referred to.

Grading of Aggregates for Bituminous Construction. Jewell R. Benson, Bureau of Reclamation.

The functions of aggregate in bitumin-aggregate systems and typical gradings for the principal types of bituminous construction for road base and surface courses, and for irrigation and flood control, are presented.

There are three types of aggregate structures: keyed type, gap-gradings, and uniformly graded aggregates.

Aggregates are classified as coarse or fine. The definitions of these classifications vary with the types of aggregate and construction, and with the specifying agency.

Two methods are used for specifying aggregate gradings. Typical gradings, obtained from the standard specifications of state highway departments, Federal agencies, and other bodies, are given for a number of road base and surface courses, and linings and facings for canals, flood channels, and revetments.

Grading of Mineral Aggregates for Portland Cement, Concrete, and Mortars. Walter H. Price, Bureau of Reclamation.

Economic considerations which influence the selection of aggregate gradings and grading specifications currently used by state and national organizations are listed and discussed. Attention is called to the lack of uniformity in screen sizes and size fractions employed by the organizations listed. Grading limits are recommended for fine aggregate with the statement that the coarse aggregate may vary through wide limits, provided the optimum amount of sand is used in the mix. It is concluded that the most ideally graded aggregate from a quality standpoint is one which will give the desired degree of workability for the least amount of mixing water.

Influence of Mineral Aggregates on the Strength and Durability of Concrete. C. W. Allen, Ohio State Department of Highways.

The author calls attention to the important influence that aggregates have on concrete simply from the fact that they constitute approximately 75 per cent of the volume. The resulting effect of individual properties

of aggregate particles is therefore evident and is reviewed in detail. Durability as discussed is confined to the consideration of the resistance of the concrete to four distinct types of action from outside factors. Field performance study is stressed as the best method of determining the suitability of mineral aggregates.

Lightweight Aggregates. R. E. Davis and J. W. Kelly, University of California.

Lightweight mineral aggregates are discussed in relation to the properties of the concretes in which they are used. Significant properties of the aggregates in concrete may include unit weight, grading, specific gravity, strength, absorption, workability, shrinkage, elasticity, durability, corrosion of reinforcement, thermal conductivity, fire resistance, and nailability; each of these properties is considered briefly. The production and characteristics of the various types of lightweight aggregate are described, including natural rocks, cinders, expanded clay or shale, processed diatomaceous shale, processed volcanic glasses, expanded vermiculite, and expanded slag. Special considerations in proportioning and manufacture of lightweight concrete, as influenced by aggregate, are given. Some factors affecting the economics of the use of lightweight aggregates are discussed.

Mineral Aggregates for Bituminous Construction. J. T. Pauls and C. A. Carpenter, Public Roads Administration.

Aggregates for bituminous construction are discussed under their two main categories: manufactured aggregates and natural or "local" aggregates. The characteristics of an ideal aggregate are proposed and the permissible departures from the ideal characteristics are suggested for the various classes of road types and service requirements. In this connection such factors as hardness and toughness, maximum particle size, grading, and asphalt-water preference are discussed. Several examples of special problems arising from the need to use apparently unsuitable local aggregates are presented and the methods that proved effective in solving them are described.

Mineral Aggregates for Low-Cost Roads and Water-Bound Macadams. Edward A. Willis and James A. Kelley, Jr., Public Roads Administration.

The greatest savings in low-cost road construction can undoubtedly be made in the full and intelligent use of all sources of local material. Experience has shown that the type of road in which a layer of granular material is used as a surface course or as a base course for a thin flexible wearing course is the most adaptable to the variety of local aggregates which may be encountered. A survey of State highway specifications shows that the fundamental differences in requirements for base and surface courses are generally recognized. Material inventories are of great values in planning a low-cost road improvement program. Small percentages of admixtures such as portland-cement bitumen and lime have been used in constructing base courses from readily available materials which fail in one or more respects to meet the generally accepted requirements. The added cost entailed in procuring and incorporating the admixture has been more than offset by savings in aggregate cost, and it would appear that this type of treatment is ready to emerge once and for all from the experimental stage.

Mineral Aggregates for Railroad Ballast. A. T. Goldbeck, National Crushed Stone Assn., Inc.

A brief historical discussion leads into the functions served by ballast, the nature of the forces to be resisted, and the desirable physical properties in mineral aggregates suitable for ballast. A summary of research investigations into the relation of physical properties of mineral aggregates with their service value as ballast precedes a final section on present-day requirements.

Mineral Aggregates in the Chemical and Processing Industries and in Certain Other Uses. Herbert F. Kriege, The France Stone Co.

The uses of aggregates of mineral composition extend into many industries beyond the general field of construction. Some of the more important of these applications are covered in this paper. The discussion deals with the type of aggregates required, their particular function in the industrial uses, specifications covering chemical composition, size, and gradation requirements, as well as the most recent (1946) tonnages so used in the United States. The topics discussed include flux stone, agricultural liming materials, filter bed media, stone dusts, mineral wool, riprap, roofing granules, and mineral aggregates essential to the production of alkalies, glass, refractories, calcium carbide, sugar, and paper.

Needed Research. D. O. Woolf, Public Roads Administration.

The methods of test commonly used for aggregates are inadequate for a suitable appraisal of the quality of the materials. This condition results from failure of research to anticipate all conditions to which a structure would be subjected, and not determining the role of the materials in this matter. A number of suggestions are made for determinations which would expand knowledge of the properties of mineral aggregates to cover, it is believed, all important features affecting the durability of the completed structure. The need of a comprehensive register of the properties of mineral aggregates is mentioned, as well as two surveys which should be instrumental in furnishing this information.

The Spectrochemical Analysis of Cements and Other Mineral Products. M. F. Hasler, C. E. Harvey, and F. W. Barley, Jr., Applied Research Laboratories.

Three basic methods of spectrochemical analysis have been used for the analysis of portland cements, ceramic materials, and various natural minerals. The first is an extension of Harvey's method of semiquantitative analysis—using the d-c. arc—to the specific materials investigated. This provides semiquantitative factors for a wide range of elements. The second is a platform-electrode method also using the d-c. arc but allowing quite accurate quantitative results. The third, providing the highest accuracy, is a briquetting method employing self-ignited, spark-like and arc-like discharges. Results obtained by each of these methods will be presented and discussed.

Thursday, June 24 9.30 a.m. Twelfth Session—*Book-Cadillac*

Held Simultaneously with the Tenth and Eleventh Sessions

Panel Discussion on Corrosion of Pressure Vessels

Report of Committee D-19 on Water for Industrial Uses. Max Hecht, Chairman.

Panel Discussion on the Influence of Non-Ferrous Metals and Their Compounds on the Corrosion of Pressure Vessels

Committee D-19 on Water for Industrial Uses, Joint Committee on Boiler Feedwater, are sponsoring a Panel Discussion on "The Influence of Non-Ferrous Metals and Their Compounds." For the last three years, this committee has sponsored programs in which the major emphasis has been on the role of mineral deposits and means for the identification of such products by special methods. This year they believe it would be of timely interest to power plant operators and equipment manufacturers to consider the effect on corrosion of the deposition as sludges, or as metals, of non-ferrous metals and their compounds in pressure vessels. It is realized that data on the subject are scarce but it is hoped by having preprints prepared well in advance of the meeting to develop the "hidden data" that might be in the files of power companies, operators, etc.

Station Design and Materials Composition of as Factors in Boiler Corrosion. R. B. Donworth, Duquesne Light Co.

Chemists have long been aware of the necessity of providing boiler feedwater that is free of corrosive chemicals and gases, and engineering development toward attainment of this condition has reached a high degree. Little is yet known, however, concerning the effects of metals, both ferrous and non-ferrous, which may be picked up from the many alloys used in piping and equipment and which appear as elements or compounds both in solution and suspension. This paper, the first of a symposium on the general subject, describes the considerations of power station design and use of materials which bear upon this problem.

Factors Influencing Boiler Corrosion. V. V. Kendall, National Tube Co.

The factors influencing boiler corrosion are gases such as oxygen, carbon dioxide, hydrogen, etc., corrosive effects of boiler water substances, galvanic effect of dissimilar metals, velocity, temperature, and pressure. A summary of the available data on the solubility of the various gases from condenser vacuum to boiler pressure will be given. The discussion will include a review and tabulation of the rates of corrosion of non-ferrous and ferrous metals used in power systems, the compounds likely to be formed from the various non-ferrous metals and their subsequent deposition in other parts of the system, and the galvanic effects of carbon and alloy steels and non-ferrous metals.

Corrosion of High-Pressure Steam Generators: Status of Our Knowledge of the Effect of Copper and Iron Oxide Deposits in Steam Generating Tubes. Richard C. Corey, Bureau of Mines.

Numerous cases of severe, pit-type, internal corrosion in high-pressure steam generators, principally of furnace wall-tubes, have been ascribed to deposits consisting almost entirely of Fe_3O_4 and copper and its oxides. Opinions of the cause of this type of attack vary widely, but in the absence of conclusive experimental proof that thin deposits of Fe_3O_4, copper or mixtures of these substances will cause pitting of steel under boiler conditions, the basis of the theories that have been proposed necessarily has been speculative. The present paper reviews critically published information on copper and iron oxide in boilers, and attempts to correlate it with the writer's personal experiences with the problem and the meager amount of theoretical data that are available, in order to provide an objective background to the problem, and to evoke discussion from others who may have the evidence that is needed to establish definitely the effect of deposits of Fe_3O_4 and copper in boilers.

Thursday, June 24 2.00 p.m. Thirteenth Session—*Book-Cadillac*

Methods of Testing

Report of Committee E-1 on Methods of Testing. J. R. Townsend, Chairman.

Symposium on Speed of Testing

This symposium is sponsored by the Section on Effect of Speed of Testing, Technical Committee on Mechanical Testing of Committee E-1. It follows a round-table discussion on speed of testing held at the Annual Meeting of the Society in 1947. Its purpose is to stimulate further study and improvement of the speed requirements in A.S.T.M. specifications.

Tests of some materials are not greatly affected by a considerable variation in testing speed. In others, the acceptance or rejection of a lot of material may depend upon the speed at which acceptance tests are conducted. In one case unnecessary speed restrictions in the specifications would increase the cost of the tests; in the other, lack of suitable speed limitations may result in rejections, delays, and increased cost.

The speed which affects test results is the rate of movement within the test specimen but this is not easily measured or controlled without special equipment. In the region in which stress and strain are proportional, the more convenient rate of stressing or loading may be substituted for rate of straining. In many cases the rate of crosshead travel may be used but it is essential to distinguish between rates measured under load and those measured without load.

A survey of A.S.T.M. specifications suggests the desirability of reviewing their speed requirements and clarifying the testing procedures involved. The papers included in this symposium discuss these factors for a wide variety of materials and indicate the limitations required and methods of measuring and controlling speeds. A general discussion from the floor is expected to bring out additional data relating to this subject.

Testing Speed Limitations for Committee A-1 Specifications for Steel. Lawford H. Fry, Steam Locomotive Research Institute, Inc.

In drawing the steel acceptance specifications of Committee A-1, it must be recognized that the tensile properties to be obtained depend on the rate of straining applied in testing. A considerable variation in rate of strain can be allowed without undue variation in tensile properties being produced, but for the sake of completeness, some testing speed limits should be set. These should be laid down at the same time that tensile values are set and for this the committee preparing the specification should be responsible.

Speed limits may be set by specifying limiting rates of crosshead speed under load or by specifying limiting rates of load application.

The Effect of Speed of Testing on Magnesium-Base Alloys. A. A. Moore, The Dow Chemical Co.

The results of an extensive series of tension and compression tests at various speeds on magnesium base alloys are reported. The yield strength was lowered by very low rates of straining where creep became a factor. At higher rates up to the maximum speed of the autographic recorder no appreciable effect was obtained. The ultimate strength and percentage of elongation were affected but little over a wide range in the speeds normally used.

The limitations and accuracy of several methods of specification of speed of testing are discussed.

Speed of Testing Wood: Factors in Its Control and Its Effect on Strength. L. J. Markwardt and J. A. Liska, U. S. Forest Products Laboratory.

Data are presented showing the effect of rate of loading and duration of stress on wood, and the importance of this factor in necessitating speed of test requirements in specifications for methods of test. In connection with the accomplishment of this desideratum, data on the sources of error in rate of loading are presented and analyzed for mechanical drive and hydraulic testing machines. Examples of machine performance in demonstration tests are presented, and methods of specifying rate of loading in the testing of wood and wood-base materials is discussed.

Effect of Speed of Test on Mechanical Properties of Plastics. Albert G. H. Dietz, Massachusetts Institute of Technology.

It has long been known that plastics materials are time sensitive in their behavior under load. A number of investigators have proposed mechanical models to picture the behavior of visco-elastic materials of various types. Mathematical expressions have been developed to represent the behavior of these mechanical systems. In all of them the rate of stressing or straining is an imporant feature.

In this paper are reported the results of tests carried out on a number of representative plastics and plastics laminates at controlled rates of crosshead motion, load, and strain. Rates of crosshead motion varied from 0.004 to 28 in. per min., rates of load varied from 4 to 80,000 lb. per min., and rates of strain ranged from 0.04 to approximately 3.2 in. per inch per min. Strain tests were carried out at controlled rates of ordinary strain and true stain.

Methods and Equipment for Controlling Speed of Testing. Lawrence K. Hyde, O. S. Peters Co.

The methods and equipment now in use for controlling speed of testing as referred to rate of application of load or rate of travel of crosshead are discussed briefly. The limitations of these methods as regards reproducibility and relation to rate of straining in the specimen suggest the need of developing methods which are more significant. A device for controlling rate of straining in the specimen is described; this strain-pacing device enables the testing machine operator to control the rate of application of load or the rate of travel of the crosshead so as to obtain a predetermined uniform rate of straining throughout the elastic range and as far into the plastic range of the test specimen as is desired. There is also described a simple time-interval marking device which records on an autographic stress-strain record the elaspsed time in increments of $\frac{1}{10}$ min., thus providing a record of the testing speed employed.

A Method of Calibrating Extensometers. W. C. Aber and F. M. Howell, Aluminum Company of America.

Report of Committee D-13 on Textile Materials. H. J. Ball, Chairman.

Report of Committee E-8 on Nomenclature and Definitions. P. V. Faragher, Chairman.

Thursday, June 24 3.30 p.m. Fourteenth Session—*Book-Cadillac*

Symposium on Methods and Procedures Used in Identifying Reactive Materials in Concrete

There are a number of ways of identifying potentially reactive materials. However, none of them has been developed sufficiently to warrant consideration as suitable for an A.S.T.M. Standard. Several of these methods have had extensive practical use and now seems a good time to compare them for simplicity of determination and correlation with actual findings in the field to the end that a suitable method may be standardized by the Society. It is hoped that the facts revealed in this symposium will be of assistance in the preparation of a standard method or methods.

Correlation of Laboratory Tests with Field Experiences of Excessive Concrete Expansion Induced by a Reaction Between the Cement and Aggregate. Thomas E. Stanton, California Division of Highways.

California studies indicate that the potential adversely reactive properties of a cement-aggregate mixture can be forecast through laboratory tests.

The paper lists and discusses a number of typical cases of failure of concrete structures through an excessive expansion resulting from a reaction between what appears conclusively to be the alkalies in the cement and some mineral or minerals in the aggregate.

In each case the reactive properties of the combination as indicated by the structure performance was subsequently checked by laboratory tests on the same materials combination.

In several cases where laboratory tests indicated certain aggregates as being potentially reactive, subsequent field inspection of structures in which the same aggregates had been used with a high alkali cement checked the forecast based on the laboratory tests.

A Wetting and Drying Test for Predicting Cement-Aggregate Reaction. C. H. Scholer, Kansas State College of Agriculture and Applied Science.

This paper describes a test for identifying aggregates which may be expected to be reactive with certain cements.

In this test, concrete or mortar specimens are subjected to a combination of wetting and drying cycles with concurrent cycles of temperature change under controlled conditions.

Apparatus and methods used in the Engineering Experiment Station at Kansas State College are described and illustrated. Certain precautions to be observed in designing such apparatus and conducting the test are suggested.

A limited amount of data is included showing how the results secured in this test compare with results secured under several other proposed methods. Data are included showing that the predictions of the test correlate very well with the service behavior of concrete in which the aggregates have been incorporated.

Correlation of Laboratory Tests with Field Experience in Alkali-Aggregate Reaction. Bailey Tremper, State of Washington Department of Highways.

A number of kinds of laboratory tests show sand and gravel from Cowlitz River, Washington, to be detrimentally reactive with high-alkali cement. Mortar bar expansion tests and freezing-thawing tests also indicate good durability when low-alkali cement is used with these aggregates. The present condition of sixteen concrete bridges, constructed with these aggregates and ranging in age from 11 to 23 yr., is described. These observations indicate a high degree of correlation between laboratory tests and field experience.

Tests Used by Bureau of Reclamation for Identifying Reactive Concrete Aggregates. R. C. Mielenz and L. P. Witte, Bureau of Reclamation.

The methods used by the Bureau of Reclamation, United States Department of the Interior, to detect deleterious alkali-reactivity of concrete aggregates are described and discussed. These methods comprise (*a*) petrographic examination and analysis, (*b*) a chemical test with NaOH solution, (*c*) tests of mortar and concrete containing the aggregate under investigation and cements of various alkali content, and (*d*) field and laboratory investigation of concrete in structures. Criteria for evaluating the significance of the determinations are developed.

Methods of Preventing the Expansion and Pattern Cracking Associated with the Alkali-Aggregate Reaction. William Lerch, Portland Cement Assn.

A Rapid Method of Testing Materials for the Alkali-Aggregate Reaction. D. O. Woolf and T. R. Smith, Public Roads Administration.

The present methods of test for the alkali-aggregate reaction which employ physical determinations cannot be used in routine examinations. A proposed method which involves the use of Mason jars is described. In this method, materials which are considered unsuitable for use are detected in a period of 28 days or less. Although the method is intended principally for the preliminary screening of aggregates in the field prior to more elaborate tests in the laboratory, it has been found suitable for furnishing quantitative results.

Petrographic Identification of Reactive Constituents in Concrete Aggregate. Bryant Mather, Corps. of Engineers.

Various techniques exist for the detection of deleteriously reactive concrete aggregates. The only technique for establishing the presence or absence of specific reactive constituents in samples of concrete aggregate is that provided by petrography.

Petrographic techniques by which reactive constituents, such as chalcedony and opal, may be distinguished from nonreactive materials such as quartz are described. Techniques are also described by means of which natural glasses may be classified as acid to intermediate or basic. Since many of these procedures involve determinations of index of refraction, several methods and criteria based on this property are given.

Thursday, June 24 8.00 p.m. Fifteenth Session—*Rackham Memorial*

Marburg Lecture, Dudley Medal, and Templin Award

The purpose of the Edgar Marburg Lecture is to have described at the annual meetings of the Society, by leaders in their respective fields, outstanding developments in the promotion of knowledge of engineering materials. Established as a means of emphasizing the importance of the function of the Society of promoting knowledge of materials, the Lecture honors and perpetuates the memory of Edgar Marburg, first Secretary of the Society, who placed its work on a firm foundation and through his development of the technical programs brought wide recognition to the Society as a forum for the discussion of properties and tests of engineering materials.

Award of Charles B. Dudley Medal to P. R. Toolin and N. L. Mochel.

Richard L. Templin Award to G. S. Barr, W. J. Gailus, J. O. Silvey, S. Yurenka, and A. G. H. Deitz.

Isotopes and Their Application in the Field of Industrial Materials—P. C. Aebersold, Atomic Energy Commission.

[See News Article on Lecture, pp. 8 and 9]

Friday, June 25 9.30 a.m. Sixteenth Session—*Book-Cadillac*

Held Simultaneously with the Seventeenth Session

Session on Fuels, Fire Tests, Building Constructions, etc.

Report of Committee D-3 on Gaseous Fuels. A. W. Gauger, Chairman.

Report of Committee D-5 on Coal and Coke. A. C. Fieldner, Chairman.

Measurement of the Reactivity of Solid Fuels by the Crossing-Point Method. J. Jonakin, P. Cohen, R. Corey, and B. Jain, Bureau of Mines.

A critical study has been made of the crossing-point method for determining the reactivity of solid fuels, and a modification developed in this investigation has been found suitable for measuring the adiabatic heating rates of small sizes of fuels. Tests of a Pittsburgh coal, an Indiana No. 5 coal, and a 900 C. experimental coke showed that (1) the order of the reaction with respect to oxygen was less than one, that of the lower rank, Indiana No. 5, being lowest; and (2) the heating rate per unit surface varied only slightly with the sieve size of the Pittsburgh coal and the coke, but considerably with that of the coarsely banded Indiana coal.

Report of Committee D-6 on Paper and Paper Products. L. S. Reid, Chairman.

Report of Committee D-7 on Wood. Hermann von Schrenk, Chairman.

Report of Committee D-10 on Shipping Containers. T. A. Carlson, Chairman.

Report of Committee D-12 on Soaps and Other Detergents. B. S. Van Zile, Chairman.

Report of Committee E-5 on Fire Tests of Materials and Construction. S. H. Ingberg, Chairman.

Report of Committee E-6 on Methods of Testing Building Constructions. L. J. Markwardt, Chairman.

Friday, June 25 9.30 a.m. Seventeenth Session—*Detroit-Leland*

Held Simultaneously with the Sixteenth Session

Session on Creep and Fatigue—Non-Ferrous

Report of Committee B-2 on Non-Ferrous Metals and Alloys. E. E. Thum, Chairman.

Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. H. S. Rawdon, Chairman.

Appendix:

Apparatus and Factors in Salt Fog Testing. V. M. Darsey and W. R. Cavanagh, Parker Rust Proof Co.

The results obtainable from the use of the salt spray fog test method B 117 - 44 T are discussed. Research work conducted since the adoption of B 117 - 44 T indicates the desirability of taking into consideration the carbon dioxide content of the salt solution in making and specifying pH. Data is presented to show the corrosiveness of the salt fog is abnormal when fluctuation of the air pressure is greater than ± 0.1 psi. Materials for constructing salt fog testing apparatus is discussed and design of a suitable cabinet is presented.

Report of Committee B-1 on Wires for Electrical Conductors. J. H. Foote, Chairman.

The Effect of Small Percentages of Silver and Copper on the Creep Characteristics of Extruded Lead. G. R. Gohn and W. C. Ellis, Bell Telephone Laboratories, Inc.

This paper discusses the effect of small amounts of silver and copper on the creep characteristics of extruded lead as determined from tests lasting for more than 16,000 hr. The data show that for complete evaluation of the creep characteristics of alloys, stress-rupture curves should be accompanied by creep rate data. The importance of obtaining creep rate data for the stresses of interest from test data rather than by extrapolation from data taken at higher stress levels, is emphasized. The paper also shows that very small percentages of added elements may have an appreciable effect on the creep characteristics.

Influence of Small Percentages of Silver on the Tensile Strength of Extruded Lead Sheathing. Howard S. Phelps, Frank Kahn, and William P. Magee, Philadelphia Electric Co.

Stress-rupture tests were made on a serices of extruded cable sheathing pipe samples of substantially pure lead to which various percentage of silver were added as metallic additions (up to 0.018 per cent silver). Extrapolation of results indicates probability of improved stress-rupture and creep characteristics at operating stresses when silver up to approximately 0.010 per cent is added to pure lead. Undesirable results are indicated for addition of silver alone in excess of 0.010 per cent.

Report of Committee B-4 on Electrical Heating, Resistance, and Related Alloys. J. W. Harsch, Chairman.

Report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought. G. H. Harndon, Chairman.

Tensile, Creep, and Fatigue Properties at Elevated Temperatures of Some Magnesium-Base Alloys. John C. McDonald, The Dow Chemical Co.

Three general types of alloys were studied, depending on the nature of the chief alloying ingredient; for example, aluminum, manganese, or cerium. Of the aluminum-containing alloys, those studied were cast AZ63 and forged AZ80. The manganese alloy is represented by forged M1. The cerium-containing alloys studied were cast EM6 and forged EM51.

Tensile properties were determined both at room temperature and at elevated temperature as a function of time of exposure at at elevated temperature. Creep properties were determined for various total extensions up to and including rupture. Fatigue tests were carried out under various conditions of loading and stress concentrations.

Report of Committee B-6 on Die-Cast Metals and Alloys. J. R. Townsend, Chairman.

Report of Committee B-7 on Light Metals and Alloys, Cast and Wrought. I. V. Williams, Chairman.

Fatigue Properties of Some Coppers and Copper Alloys in Strip Form. H. L. Burghoff and A. I. Blank, Chase Brass and Copper Co.

The results of reversed bending fatigue tests on three types of copper, five copper-zinc alloys, and four other copper base alloys in the form of 0.032-in. strip are given in this paper. *S-N* curves for all of the materials are included and the results are correlated in graphs showing the relationships between fatigue strength, tensile strength, composition, degree of reduction by cold rolling, grain size, and angle of applied stress with respect to the rolling direction. The effects of additions of tin to copper and red brass and of lead to high brass are described.

Report of Committee B-8 on Electrodeposited Metallic Coatings. C. H. Sample, Chairman.

Report of Committee B-9 on Metal Powders and Metal Power Products. W. A. Reich, Chairman.

Report of Committee E-3 on Chemical Analysis of Metals. G. E. F. Lundell, Chairman.

Friday, June 25 2.00 p.m. Eighteenth Session—*Detroit-Leland*

Held Simultaneously with the Nineteenth Session

Session on Cement, Concrete, and Concrete Aggregates

Report of Committee C-1 on Cement. F. H. Jackson, Chairman.

Report of Committee C-9 on Concrete and Concrete Aggregates. K. B. Woods, Chairman.

Sanford E. Thompson Award. To W. C. Hanna, Chief Chemist and Chemical Engineer, California Portland Cement Co.

Laboratory Studies of the Effect of Cement Composition and Finenesson the Resistance of Concrete to Freezing and Thawing. George J. Verbeck and Paul Klieger, Portland Cement Assn.

Effect of Delayed Mixing of Prebatched Moist Aggregates and Cement on the Strength and Durability of Concrete. Walter H. Price and John W. Robison, Bureau of Reclamation.

Contractors frequently have resorted to concreting methods which have included pre-batching of the damp aggregates and cement in hoppers, bins, or truck compartments. Often the inspector is confronted with the problem of acceptance or rejection of batches because of a prolonged delay which allowed the cement to partially hydrate due to its contact with the damp aggregates.

In order to determine the effect of this batching arrangement upon the physical properties of the concrete, a small working model stimulating these conditions was set up in the laboratory and tests were made to determine the effect of partial pre-hydration of the cement on the quality of the concrete.

For the particular moisture conditions investigated (7.5 per cent moisture in the sand and 2 per cent in the gravel), the strength loss amounted to 4.5 per cent per hour of delay between batching and mixing. Delays up to 3 hr. produced no significant differences in drying shrinkage, moisture loss, or absorption, while the freezing-and-thawing tests show that the delay in mixing, up to about 2 hr., results in an increase in the durability of the concrete even though it was necessary to increase the water-cement ratio and there was a decrease in compressive strength.

Research on Concrete Durability as Affected by Coarse Aggregate. Harold S. Sweet, Joint Highway Research Project, Purdue University.

The results of laboratory studies undertaken to establish the characteristics of coarse aggregates with known field performance records are reported. It is concluded, on the basis of the comparison of field performance, aggregate characteristics, and resistance of laboratory concrete to freezing and thawing, that freezing-and-thawing tests on concrete beams containing the aggregate can be used to differentiate Indiana materials with good field performance from those with bad performance. It is important that the aggregate be incorporated in the laboratory concrete in a saturation condition representative of the saturation in which it is used in field construction. The mortar in the concrete should have a low degree of saturation; ordinarily this will be the case if the concrete has an initial air content greater than two per cent.

No correlation with field performance was shown by the aggregate characteristics of apparent specific gravity, bulk specific gravity, absorption, total pore space, general geologic origin, quantity of impurities (in the case of limestones), resistance to the sodium sulfate soundness test, or resistance to freezing and thawing in the unconfined state. The factor of volume of pores smaller than 0.005 mm. in diameter showed good correlation with the field performance, probably because of the influence of pore size on water-retention and capillary characteristics of the rock material.

The Effect of Repeated Loading on the Bond Strength of Concrete—Supplement I. C. W. Muhlenbruch, Carnegie Institute of Technology.

The repeated loading machine previously described, 1945 issue of the A.S.T.M. *Proceedings*, has been modified to operate at twice the previous speed and to accommodate loads equal to 60 per cent of the static pull-out capacity of a 5-in. specimen into which a ⅝-in. diameter bar has been embedded. Additional modifications of the apparatus permit the measurement of slip during load at both the loaded and unloaded ends of the bar. Studies are being made of plain bars, ordinary deformed bars and the new "Hi-Bond" bar. Present data show that the loaded end of a deformed bar slips at a rate which is 34 per cent greater than the slip rate for the unloaded end of the bar and that both ends slipped continuously throughout the application of repeated load. When present studies are completed it is expected that some of the plain bars will have been loaded to actual failure under repeated loading so that the conventional stress-cycle diagram can be given.

Report on Committee C-11 on Gypsum. L. S. Wells, Chairman.

Report on Committee C-16 on Thermal Insulating Materials. Ray Thomas, Chairman.

Friday, June 25 2.00 p.m. Nineteenth Session—*Book-Cadillac*

Held Simultaneously with the Eighteenth Session

Session on Rubber, Plastics, Insulating Materials, and Engine Antifreezes

Report of Committee D-15 on Engine Antifreezes. H. R. Wolf, Chairman.

Requirements of an Engine Anti-Freeze and Methods of Evaluation. D. H. Green, J. C. Kratzer, and P. I. Emch, National Carbon Co., Inc.

The requirements of an engine antifreeze and the methods of evaluating its performance are briefly discussed from the point of view of a large producer and national marketer of antifreezes. These requirements are broadly classified as: (1) dependable freezing protection, (2) adequate engine cooling, (3) effective protection against corrosion, and (4) retainability in the cooling system. An integrated test program of laboratory, full-scale engine dynamometer, and vehicle driving procedures has been adopted for antifreeze development and evaluation. Each phase of this integrated test program serves a special purpose and none has been found satisfactory as a substitute for any other phase.

The Detection of Corrosive Sulfur Compounds in Mineral Transformer Oil. Frank M. Clark and Edward L. Raab, General Electric Co.

The A.S.T.M. Test D 117 is set up to detect corrosive free sulfur. In this it functions satisfactorily. The trend to higher operating temperatures in mineral oil-filled transformers, however, compels consideration of the corrosivity of combined sulfur compounds. In this evaluation the present test for free sulfur is not satisfactory.

To meet this requirement and industrial trend, a new test for evaluating the corrosivity of mineral oils containing combined sulfur compounds has been developed. In the development of this test the factors evaluating the corrosivity of the sulfur containing oils are described. These factors include the effect of oxidation, temperature, metal catalysts, inhibitors, and so forth. The test developed comprises heating the oil in contact with copper or silver for 19 hr. at 140 C. in the absence of air or oxygen. The application of the test to typical commercial transformer oils is described.

Report of Committee D-11 on Rubber and Rubber-like Materials. Simon Collier, Chairman.

Nontoxic Rubber for Gas Masks. S. H. Katz, Chemical Corps Technical Command.

Some accelerators, antioxidants, and vulcanizing agents for natural rubber caused physiological reactions on the skin of wearers of gas masks. Limiting the chemical ingredients in the rubber to those proved by tests to cause no physiological effects and to exclude others was necessary. The patch tests employed in accordance with Chemical Corps specifications for acceptance of rubber parts of gas masks, which contact a wearer's skin, are outlined. Twenty-five accelerators and nineteen antioxidants proved innocuous in the proportions needed; usually about 1 to 2 parts per 100 parts of rubber by weight, are listed. The listed materials would probably be innocuous if compounded with synthetic rubbers, but this has not been proved in the limited experience with synthetic rubber gas masks. The listed chemical materials should not be accepted as suitable in articles contacting a wearer's skin for extensive periods, other than gas masks, without first undergoing patch tests and other tests appropriate for the purposes.

Report of Committee D-20 on Plastics. Robert Burns, Chairman.

The Effect of Temperature on Creep of Laminated Plastics. W. N. Findley, and W. J. Worley, University of Illinois; C. N. Adams, formerly University of Illinois, now Monsanto Chemical Co.

The results of creep tests of two fabric laminated plastics are reported. The tests were conducted at three different temperatures, 43, 77, and 128 F., for a time interval in excess of 1700 hr. Specimens were tested at several different stresses for each of the three temperatures. The relative humidity of the air surrounding the specimens was controlled at about 50 per cent for tests at all three temperatures.

Dimensional changes under no stress and changes in weight of the material were recorded as well as creep. It was observed that the creep rate at a given time and stress was nearly a linear function of temperature for both materials. At the highest of the three temperatures the weight of the laminate decreased during the creep tests and the unstressed length decreased, while at the lowest temperature the weight and the unstressed length increased.

Report of Committee D-14 on Adhesives. R. C. Platow, Chairman.

Report of Committee D-17 on Naval Stores. V. E. Grotlisch, Chairman.

Report of Committee D-9 on Electrical Insulating Materials R. W. Orr, Chairman.

Committee C-1 Approves Addition to Cement

IT IS announced by A.S.T.M. Committee C-1 on Cement that the material known as "109-B" (composed essentially of 2 methyl 2-4 pentane diol) has been declared acceptable as a nonharmful addition to the cements covered in A.S.T.M. Standard Specifications for Portland Cement (C 150). In these specifications, additions of material as grinding aids are authorized when not exceeding 1.0 per cent of other materials and when found to be not harmful. This recognition is in accordance with the policy of the committee and the Society in indicating the acceptability of an addition to portland cement following the completion of suitable tests or review of existing data.

When the 1948 revision of Specifications C-150 is published, footnote 3 to the specifications covering nonharmful additions will provide for inclusion of this material as follows: "The committee has declared as not harmful the inclusion of... the material known commercially as "109-B" (composed essentially of 2 methyl 2-4 pentane diol), marketed by the Master Builders Co., when added in an amount not exceeding 0.03 per cent by weight of the cement, except that in Type III cement a maximum of 0.05 per cent by weight may be used."

A.S.T.M. Members At International Conferences

SEVERAL members of the Society will participate in international conferences being held abroad during the next few months. At the Rubber Technology Conference in London, June 23 to 25, Mr. H. G. Bimmerman, E. I. du Pont de Nemours and Co., Inc., will represent Committee D-11 on Rubber and Rubber-like Materials, and Mr. A. J. Warner, Federal Telecommunication Laboratories, who is returning to England, will represent Committee D-9 on Electrical Insulating Materials, and Committee D-20 on Plastics. The appointment of Messrs. Bimmerman and Warner is in response to an official invitation extended to the three committees to be represented at the conference. Mr. Bimmerman has also been appointed as the American representative to the conference being held in London, June 28 and 29, to organize the ISO Project on Rubber.

In the field of textiles, Professor H. J. Ball, Past-President of the Society, and who for a number of years has served as Chairman of Committee D-13 on Textile Materials, and Mr. A. G. Scroggie, E. I. du Pont de Nemours and Co., Inc., who is Vice-Chairman of Committee D-13, will on nomination of the Society attend a conference to organize a new ISO Project on Textiles to be held in Buxton, England, June 7 to 12. These two individuals will form part of an American delegation to this conference. Professor Ball also expects to attend the meetings of the British Textile Institute being held in Buxton, June 2 to 5.

ASTM Bulletin

MAY 1948

NO. 152

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

First Pacific Coast Meeting of the Society

The Board of Directors is pleased to announce that a meeting of the Society will be held on the Pacific Coast next year. The dates selected are October 10–14, 1949, and the location is San Francisco. The sessions will be held in the Fairmont Hotel, which will be convention headquarters; hotel accommodations for the members and visitors have been reserved in the Fairmont and the Mark Hopkins Hotels. These two hotels are across from each other on California Street, on the world-famous Nob Hill.

This decision constitutes acceptance of the invitation extended over a year ago by the Northern and Southern California District Councils for the Society to hold a national meeting on the Pacific Coast. Preliminary discussions last year revealed the very keen interest of our members in the far West in acting as hosts to a national A.S.T.M. meeting, and established the availability of suitable accommodations for the meeting at the time selected. This time was chosen to come not too close to the Annual Meeting at the end of June, 1949, and having in mind the fact that October is a delightful month in San Francisco and will undoubtedly work in well with plans of members who may wish to combine the meeting with a fall vacation.

Technical Program:

During the recent visit of President Boyd and Secretary Warwick to the coast, many arrangements for the meeting were completed which will be announced in due time. The most important thing, of course, was to outline the technical program, for which purpose a committee under the chairmanship of Professor R. E. Davis, University of California, is being formed. At the moment, it is planned to hold possibly twelve sessions during the four days of the meeting, at which technical papers and discussions will be presented on a number of subjects, among which the following are being considered: metals, with particular reference to fatigue, creep and formability properties; cement, concrete, asphalt and soils, tied in with highway and airport construction, but not limited to such uses; petroleum; paint, manufactured masonry units; timber; rubber and plastics; dynamic stress measurements; and applications of statistical analysis. While some of these subjects have been chosen because of their special interest to technical people or to industry on the Pacific Coast, they are—as will be seen—a good cross-section of the technical work of the Society and should have a wide appeal to our members generally. It is planned that no more than half the papers will be contributed by far western members, for it is the desire of the program committee to present to those attending, the results of research and investigation in the subjects throughout the entire membership.

Committee Meetings:

This will not be a business meeting of the Society, so that Society action on committee reports is not planned. It is expected, however, that certain technical committees of the Society will hold their fall meetings in conjunction with this Pacific Coast meeting. Committee C-1 on Cement has already decided to meet in San Francisco at that time; Committee D-18 on Soils for Engineering Purposes is expected to do likewise; and several other committees, including Committee D-2 on Petroleum Products and Lubricants, have such a plan under consideration. An announcement of the Pacific Coast A.S.T.M. meeting will be sent soon to each technical committee with an invitation to hold a meeting in San Francisco at that time. For all committees who would find it suitable to do so, excellent facilities for meetings are available.

Features:

But, technical sessions and committee meetings will be only a part of the meeting program. Plans are already being made for various entertainment features, with special thought to the entertainment of the ladies who it is hoped will be present in considerable number. Visits to industrial plants, universities and laboratories, and to points of scenic and historic interest will be provided. Special attention is being given to furthering the social contacts that this meeting will afford, and, as a part of these plans, a banquet will be one of the big features of the meeting.

Committees for all these features, and for such important details as hotels, registration, transportation, publicity and finances will function under the direction of a General Committee on Pacific Coast Meeting which is soon to be appointed and which will be in over-all charge of all arrangements for the meeting. The officers of the District Councils have been cooperating with the Board of Directors in setting up these provisional plans, and they have the sincere thanks of the Board for their earnest efforts thus far. They are: Northern California District Council, Dozier Finley, *Chairman*, G. H. Raitt, *Vice-Chairman*, P. V. Garin, *Secretary*; Southern California District Council, R. B. Stringfield, *Chairman*, C. E. Emmons, *Vice-Chairman*, H. W. Jewell, *Secretary*.

Look in future issues of the BULLETIN for more about this meeting. For the present, just mark October 10–14, 1949, San Francisco, on your calendar as one of the big events in the history of A.S.T.M. that you must attend if you can.

1947 *Proceedings* Issued

In April the printer completed work on printing and binding the 1206-page volume comprising the 1947 *Proceedings*. The first 450 pages of the *Proceedings* cover the President's address, Report of the Board, and the annual reports of the numerous technical committees. These reports give a good picture of committee activities as reported at the 1947 Annual Meeting.

About 750 pages of this large volume are devoted to the technical papers, with discussion, and the Edgar Marburg Lecture on "Engineering Laminates." These technical papers cover important topics in the field of metals, rating the exposure of test panels, the symposium on measurement of entrained air in concrete, and significant papers on cement, concrete, lime, and other topics, including the 60-page discussion on the identification of water-formed deposits.

Quite a number of the papers in the *Proceedings* will be seen by some of the members for the first time although most were preprinted and during the past few months it was possible to print a number of papers that had not been distributed before the meeting. The following list notes the papers that were not distributed as preprints before the Annual Meeting. Some of these are outstanding contributions; in fact among them are two award-winning papers.

* A Study of the Transition from Shear to Cleavage Fracture in Mild Steel—H. E. Davis, E. R. Parker, and Alexander Boodberg
- Physical Characteristics of Steel for Tubular Products—Arthur B. Wilder
- Creep and Creep-Rupture Testing—G. V. Smith, W. G. Benz, and R. F. Miller
* Fatigue Characteristics of Rotating-Beam *versus* Rectangular Cantilever Specimens of Steel and Aluminum Alloys—F. B. Fuller and T. T. Oberg
* The High-Temperature Fatigue Strength of Several Gas Turbine Alloys—P. R. Toolin and N. L. Mochel
* Fatigue Characteristics of Some Copper Alloys—H. L. Burghoff and A. I. Blank
* The Creep Characteristics of Copper and Some Copper Alloys at 300, 400, and 500 F.—H. L. Burghoff and A. I. Blank
- Hardness Conversion Chart for Nickel and High-Nickel Alloys—F. P. Huston, Jr.
* Some of the Effects of Cadmium, Zinc, and Tin Plating on Springs—John R. Gustafson
* The Effect of Blends of Natural and Portland Cement on Properties of Concrete—A. G. Timms, W. E. Grieb, and George Werner
* Methods for the Determination of Soft Pieces in Aggregate—D. O. Woolf
* Unfavorable Chemical Reactions of Aggregates in Concrete and a Suggested Corrective—W. C. Hanna
* Polarographic Determination of Tetraethyl Lead in Gasoline—Richard Borup and Harry Levin
* Tests for Thermal Diffusivity of Granular Materials—William L. Shannon and Winthrop A. Wells
- Uplift Soil Pressure on Bridge Foundations as Revealed by Shear Tests—G. O. Kerkhoff and W. S. Housel
* The Use of the Maximum Principal Stress Ratio as the Failure Criterion in Evaluating Triaxial Shear Tests on Earth Materials—W. G. Holtz

This volume of *Proceedings*, like its predecessors, is marked by the large amount of discussion on various problems covered in the papers. This discussion gives a broader viewpoint of the particular subject and is considered a most important part of the *Proceedings*.

A copy of the *Proceedings* goes to each member of the Society, and it is considered one of the distinct attributes of membership. Extra copies to members are $8; list price, $12.

*These papers were printed in October-November and, as noted in The Bulletin, were available separately at nominal prices.

Plastics, Load Tests of Soils, Covered in Publications

The Symposium on Load Tests of Bearing Capacity of Soils, which in published form is a 156-page book, has recently been issued, and shortly to be released for press is the 1948 Compilation of Standards on Plastics. Each of these books is of widespread interest in the respective fields.

Load Tests of Bearing Capacity of Soils:

This symposium, comprising seven technical papers, held at the 1947 Annual Meeting, was sponsored by Technical Committee D-18 on Soils for Engineering Purposes through its Subcommittee IX on Methods of Testing for Bearing Capacity of Soils in Place (Load Tests). The Symposium Committee consisted of W. S. Housel, *Chairman*, University of Michigan; F. J. Converse, California Institute of Technology; and Hamilton Gray, University of Maine.

In recent years load tests to measure the bearing capacity of soil masses have become of increasing importance in engineering practice in spite of wide diversity in test procedure, methods of analysis and application of results in design. The use of this type of test received great impetus in the war-time airfield construction and in the post-war evaluation programs. The publication of the papers presented as a part of this symposium with the report of the Symposium Committee bring together in one reference the most complete compilation of recent information on the subject of Load Tests.

This book is profusely illustrated, and there is a considerable amount of discussion. Also included is a helpful bibliography of 76 references in addition to authors' references. Aggregating 156 pages, the book in heavy paper cover can be procured by members at $2.25, the list price being $3 This is Special Technical Publication No. 79.

Standards on Plastics:

This extensive publication, to aggregate some 640 pages, will give in their latest form the more than 100 specifications and tests as developed by the Society chiefly through the work of its Committee D-20 on Plastics. There has not been a revised compilation in this field for over two years, and the book will therefore be of particular interest and service. The 1948 edition is a greatly expanded one and its size and the large number of items included are truly an indication of the intense activity in this field. The book can be procured by members at $3.40 per copy, the list price being $4.50.

The above two publications and others issued early in 1948 were covered on the special Members' Order Blank mailed early in May to each member.

Index to A.S.T.M. Standards

The combined Index to the 1946 Book of A.S.T.M. Standards and 1947 Supplements should be available sometime in May. Work on this publication cannot be expedited until the last part of the Book of Standards and supplements has been virtually completed. This means that the 260-page 1946 Index to Standards cannot be

completed much before about May 20.

This Index is a decided convenience since it will cover *all* five Parts of the Book of Standards and Supplements. The main portion of the Index lists the specifications under appropriate key words but use is made of convenient cross references so that the material will be as concise as possible. Under each key heading an effort is made to select the most significant word in the title of the specifications so that there is some alphabetical sequence.

A most valuable part of the Index is the list of standards in numeric order of their serial designations, and in these lists, too, reference is made to the official source of latest publications.

Distribution of the Index.—A copy of the Index will be sent to each A.S.T.M. member and committee member, and in addition a copy is furnished to all members or nonmembers who *purchase* any parts of the book.

The Index is distributed on request and several thousand purchasing agents and others who are concerned with A.S.T.M. standards get the publication regularly. Some organizations get several copies to distribute to their key technical people.

We recommend that this Index be placed convenient to the Book of A.S.T.M. Standards. Its use may save much time in locating any particular items.

Important New Publication on Engine Test Methods for Rating Fuels

A SIGNIFICANT new publication came from the printer late in April constituting the A.S.T.M. Manual of Engine Test Methods for Rating Fuels. Behind this important compilation sponsored by the Division on Combustion Characteristics of A.S.T.M Committee D-2 lie many years of intensive research and testing work by hundreds of the country's leading technologists concerned with fuel and engine design, and the practical spade work involved in getting the publication ready involved interminable hours of work on the part of those immediately responsible, including particularly Dr. Arman E. Becker, Chairman of the Editorial Section, Division of Combustion Characteristics, a leading authority in this field, and the Society's Standards Editor, P. J. Smith.

While the publication is of particular concern to those who are testing and evaluating fuels and others in both the petroleum and automotive field, the basic principle which made the book possible is of general interest even though it may seem to be an old story in so many successful ventures of the Society. That principle is the wholehearted cooperation of the leaders concerned.

Purpose.—The chief purpose of the Manual is to improve the utility of the five A.S.T.M. methods for determining combustion characteristics of fuels, first by compiling these with the extensive illustrations under one cover, and second, supplementing the methods by extensive information and data not given in the tests proper. The five methods, namely, the Motor, Research, Aviation, Supercharge, and Cetane methods, are used widely not only in this country, but throughout the world, and most of the laboratories where the tests are made are procuring copies of this publication. The benefits from the intensive work which has been put on the new volume are far reaching—in fact, reaching to the four corners of the globe.

Responsibility for the manual was assigned to an editorial section headed by Dr. Becker, and with the following members assisting in the preparation and editing of the entire manual, but with a specific assignment as follows:

I. Apparatus—Leo A. McReynolds
II. Reference Materials—Arman E. Becker
III. Operation—Hudson W. Kellogg
IV. Maintenance—Carl E. Habermann
V. Building Requirements—Edward J. McLaughlin
VI. Installation—Royce Childs
Tables and Charts—Bruno R. Siegel
Illustrations—Prescott C. Ritchie

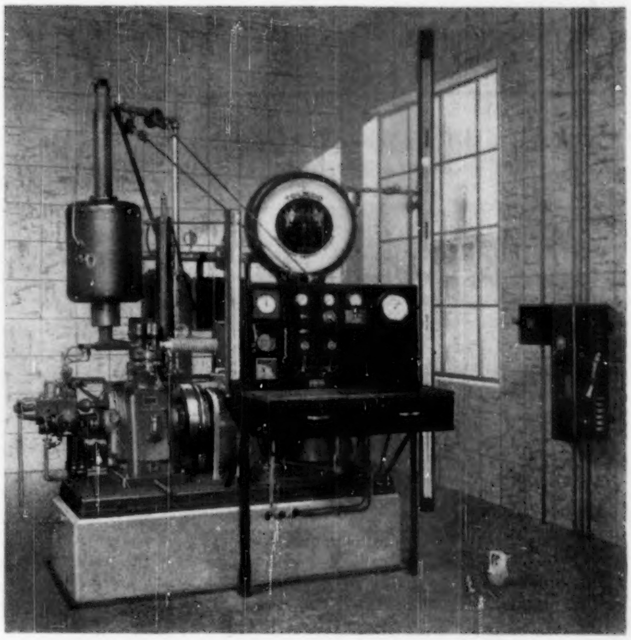
Other members of the Division on Combustion Characteristics and the officers of Committee D-2 cooperated. D. B. Brooks, National Bureau of Standards, heads the D-2 division responsible and H. M. Trimble, Phillips Petroleum Co., is secretary.

The combustion characteristics of fuels are a most important factor along with engine design and operating conditions in determining the efficiency and output of an engine. As demands for bigger and better engines developed, research on methods of determining efficiency of fuels was intensified. Thousands of miles of road tests were made and much research work was undertaken, and early in the 1930's engines for laboratory testing were developed. In 1933 the A.S.T.M. issued its first test for knock characteristics.

This picture termed "Cruising" is a reduced version of one of the full page illustrations used in the Knock Test Manual.

A. E. Becker

(Photo-Blackstone Studios, Inc.)



Front View of Supercharge Unit

The A.S.T.M. Supercharge Aviation Engine Unit for determining knock characteristics of aviation fuels by the Supercharge method consists of a single-cylinder engine of continuously variable compression ratio for operation at continuously variable manifold pressure and fuel-air ratio, together with suitable loading and accessory equipment and instruments, mounted on a stationary base.

the so-called "Motor method." Subsequently, other methods for different fuels and purposes were developed. Dr. Becker, who is now with the Standard Oil Development Co. of New York, has been one of the leaders in all of this work; in fact, he has been concerned with fuel and lubricant problems since 1920 when he went with the company. He was responsible for the preparation of one of the first manuals in this field in the early 1930's, and later worked with the CFR Committee in issuing its manuals which are now superseded by the new combined A.S.T.M. book. It was thus natural that he should head the Editorial Committee for the new manual. A graduate of Marietta College and Harvard, Dr. Becker has been active in the work of a number of organizations, and is a former Vice-President of the Society of Automotive Engineers.

Members of the Society have had an opportunity to order copies of this publication at the special price of $6. The list price to nonmembers is $8. All told, the volume covers some 336 pages and there are almost 110 figures, including photographs, charts, and diagrams incorporated, many of them full-page illustrations or charts.

To implement the use of the methods certain supplementary material has been published separately, including three charts that are available in pad form. Certain tables incorporated in the book are to be produced on letter size sheets for mounting and use in the laboratory.

ERRATA

Corrections in Oscillograph Test for Rubber (D 945)

ONE of those obvious errors that sometimes escape careful review is found in the Tentative Methods of Test for Mechanical Properties of Elastomeric Vulcanizates Under Compressive or Shear Strains by the Mechanical Oscillograph (A.S.T.M. Designation: D 945), which appears on p. 145 of the Compilation of A.S.T.M. Standards on Rubber Products. In Section 9(*h*) of Methods D 945, the formulas for calculation of energy to produce any desired deformation are given as follows:

$$e_c = 181.40A$$
$$e_s = 22.67A$$

These formulas should be changed to read as follows:

$$e_c = 40A$$
$$e_s = 10A$$

Errors in Steel Specifications—Nuts and Boiler Plate

An error in reference appears in the Standard Specifications for Carbon- and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service (A.S.-T. M. Designation: A 194) as printed in the yellow stickers issued with the 1947 Supplement to Book of A.S.T.M. Standards, Part I-A, and also in the specification as printed in the March, 1948, A-1 Piping Compilation. A correction should be made as follows:

Page 146, Piping Compilation (also the editorial change as outlined for Specifications A 194 in the Part I-A yellow stickers)—In Section 13(*c*) change the present reference to ASA Standard No. B18.2-1941 to the following: "American Standard for Screw Threads for High Strength Bolting (ASA No. B1.4-1945)."

In the Standard Specifications for Low and Intermediate Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities (Plates 2 in. and Under in Thickness)(A.S.T.M. Designation: A 285-47), as printed in Part I-A of the 1947 Supplement, an error appears in the chemical composition required for acid open hearth steel of flange quality. It should be corrected as follows:

Page 6, Supplement—In Table I for grades A, B and C flange quality steel change the maximum phosphorus requirement for acid steel from the present "0.06" to read "0.05" per cent.

Paper on Use of the Rossi-Peakes Tester in Measuring Viscosity of Plastics

Our attention has been called to the incorrect insertion of Figs. 3 and 4 in the paper by F. E. Piech and W. E. Gloor "The Use of the Rossi-Peakes Flow Tester in Measuring the Apparent Viscosity of Plastics at Temperatures from 115 to 175 C.," which appeared in ASTM BULLETIN No. 151, March, 1948, p. 72 (TP 80). The illustration identified as Fig. 3 should be Fig. 4 and *vice versa*.

TECHNICAL COMMITTEE NOTES

Committee B-1 on Wires for Electrical Conductors

The high level of activity in Committee B-1 was noted in the article in the December, 1947, BULLETIN, and at the New York meetings on March 18 and 19. Seven new specifications were reported complete and ready for letter-ballot action and one method of test completely revised and rewritten has achieved the same status.

The Subcommittee on Methods of Test and Sampling Procedure has completely revised and rewritten Method B 193 which, with changes in scope and title, will now be a Method of Test for Resistivity of Electrical Conductor Materials. This subcommittee also has in process a general method of test for conductors as well as a specification covering sampling procedure. The Subcommittee on Rods for Processing into Conductors has completed a Specification for Rolled Aluminum Rods for Electrical Purposes.

The Subcommittee on Conductors of Copper and Copper Alloys has completed a new Specification for Cored-Annular Concentric-Lay-Stranded Copper Conductors. A modification of the edgewise bend testing requirements in the Specification for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors (B 48) has also been completed, as well as a modification in the tensile-elongation requirements for soft wire removed from cable in the Specification for Concentric-Lay-Stranded Copper Conductors (B 8). Editorial changes in two of the specifications for trolley wire (B 9 and B 47) were also agreed upon and for these two specifications and also for the other trolley wire specification (B 116) the subcommittee has a task group assigned to (1) the preparation of a clause covering a weight-density method for area determination, (2) a review of all tolerances, and (3) an acceptance test for contour which will utilize fittings furnished by the purchaser. This subcommittee also voted to postpone for the present any change in the number of decimal places or significant figures in its specifications pending the outcome of the proposed revision of Circular No. 31 reported in the December article on Committee B-1 activities.

The Subcommittee on Composite Conductors of Copper and Steel reported it had completed three new specifications during the year. These specifications are for: (1) Copper-Covered Steel Wire, (2) Copper-Covered-Steel and Copper Composite Conductors, and (3) Concentric-Lay-Stranded Copper-Covered Steel Conductors.

The Subcommittee on Conductors of Light Metals also reported that three new specifications had been completed and were ready for committee action. These are the Specifications for Hard-Drawn Aluminum Wire; for Aluminum Cable Steel Reinforced; and for Concentric-Lay-Stranded Aluminum Conductors, Hard-Drawn.

The specifications covering the copper-covered steel wires and aluminum in various combinations are, as was noted in the December BULLETIN, the first specifications of this type ever written in A.S.T.M. and Chairman Foote congratulated his subcommittee chairmen for the large volume of work which they had completed in a short space of time since the subcommittees were reorganized last year.

Cement Committee Meets in West

THE Spring Meeting of Committee C-1 on Cement was held on February 27–28 at the Hotel Shirley-Savoy in Denver, Colo., following the Annual Meeting of the American Concrete Institute. An attendance of 80 members and visitors was recorded.

Matters of interest reported by the several working subcommittees included: progress in formulating a direct method for determining aluminum oxide in cement; a summary of various method of tests for reactivity of aggregates in mortar and concrete; a pilot study of the 1:5 mortar bar test in three laboratories to be followed by larger cooperative series of tests by twelve laboratories in respect to sulfate resistance; completion of a flow table design on which comments will be solicited; and progress on a cooperative investigation of the relative value of the tensile, compressive, and flexural strength tests of the matter in predicting the flexural and compressive strengths of concrete.

The Working Committee on Additions presented a new definition of the term "addition" which was accepted, referring also to the revised definition of the term "admixture" adopted by Committee C-9 on Concrete and Concrete Aggregates. Additional progress was reported on the SO_3 content project in which very close agreement has been reached in the data for determining the optimum SO_3 content for each type of cement. The second part of this program will be concerned with the effect of the SO_3 content of concrete durability with these optimums.

A revision of the Specification for Portland Cement (C-150) was approved which

FRONT ROW, Left to right, R. E. Davis, J. C. Evans, G. C. Wilsnack, N. T. Stadtfeld, R. R. Litehiser, E. E. Berger, H. D. Baylor, D. Wolochow, F. H. Jackson, R. F. Blanks, W. C. Hanna, Louis Anderson, H. H. Leh, S. G. Thyrre, H. K. Cook. BACK ROW, Left to right, H. F. Gonnerman, G. L. Lindsay, J. R. Dwyer, L. R. Pritchard, R. E. Bollen, Bailey Tremper, M. A. Swayze, Herbert Insley, J. J. Fox, W. S. Weaver, A. A. Bates, C. H. Cash, L. R. Forbrich, F. O. Anderegg, T. E. Stanton, H. S. Meissner, H. L. Vanderwerp, R. H. Fasnacht, W. J. McCoy, E. P. Newhard, G. A. Mansfield, C. H. Scholer, A. D. Conrow, H. L. Kennedy, D. E. Parsons, F. R. McMillan, R. B. Young.

will equalize the strength requirements at 7 and 28 days for both Type II and Type V cements. Also approved was the recommendation that a third type be added to the Specification for Air-Entraining Cement (C 175) which will apply to high early strength cement. A study leading to the revision of the Specification for Natural Cement (C-10) is being made in which chemical requirements are being considered as a control for the degree of burning.

Glass Committee Holds Meeting

COMMITTEE C-14 on Glass and Glass Products held a luncheon meeting at the Palmer House in Chicago on April 28, with 24 in attendance. This meeting was held during the Annual Meeting of the American Ceramic Society. The formation of a proposed subcommittee on illuminating glass was deferred pending further information as to the extent of coverage in this field by a sectional committee under the procedure of the American Standards Association, now being organized. A proposed test on abrasion resistance of glass and plastics is in process of formulation by the sectional committee for safety glass (ASA Z26), which, when completed, will be presented to Committee C-14 for consideration. The Subcommittee on Nomenclature and Definitions reported the completion, by the American Ceramic Society Standards Subcommittee, of a glossary on glass including 15 definitions, these definitions to be submitted to Committee C-14 for adoption. Proposed methods of sampling cellular load and nonload bearing glass block were recommended for submittal to letter ballot of the committee. Additional recommendations for committee action included a method of sampling of glass containers and three test methods on durability of glass. These methods will cover powdered glass, bottles attacked by water and bottles attacked by acid.

Committee on Drain Tile Amalgamated in Committee C-15 on Manufactured Masonry Units

IN CONNECTION with the discharge of A.S.T.M. Committee C-6 on Drain Tile which is one of the oldest A.S.T.M. committees, having been organized in 1911, the long-time secretary, W. J. Schlick, wrote an interesting letter to the members of his committee and because of some of the sentiments expressed in the letter, some portions of it are reproduced below. The chairman of the committee, Dean Anson Marston, is a much beloved member of the American engineering fraternity, and is widely known.

Committee C-15 has organized a new standing subcommittee to handle the work formerly under the jurisdiction of Committee C-6.

Dear Friends:

Most of you know that the Board of Directors for the Society has had the future of Committee C-6 under consideration for some time. I have received word that at a recent meeting it was decided to discharge the Committee and transfer its work and field to Committee C-15, on Manufactured Masonry Units (D. E. Parsons, Chairman). Future work on standards for drain tile will be under the jurisdiction of a subcommittee which in due course will be organized by Committee C-15.

The organization meeting of Committee C-6 was held in Chicago, September 28 and 29, 1911. There were 16 members, eight representing "manufacturing interests" and 8 representing the "consuming interests." Five of the later group were from education institutions; two of these five, Dean Marston and Dean Turneaure, are still members of the Committee. The first standards for drain tile were adopted in 1914; revisions, mostly extensions, were made in 1916, 1919, and 1924. In June, 1938, a canvas of committee members and of a widely distributed list of consumers showed wide use of the standards, with no suggestions for other than minor revisions. The intervening years have produced no requests for revisions. These facts attest the high quality of the work done in formulating those standards.

It is interesting to note also that the Committee has had only one chairman, Dean Marston. The older members will be glad to know that while the Dean finds it necessary to curtail his activities, his eyes still have that merry twinkle, and he is fully alive to the implications of current developments, as, for example, the place of atomic power in our engineering curricula.

I am asked to express to you the Board's appreciation of your services on the Committee. Dean Marston extends his greetings, together with his thanks for your cooperation and his commendation for work well done; only work exceptionally well done could have produced a standard which is generally used, and found satisfactory, a quarter of a century after its adoption. Since this letter should complete my duties as your secretary, to you all, Greetings and Thank You.

W. J. SCHLICK
Secretary, Committee C-6

Committee on Thermal Insulating Materials Celebrates First Decade

AT ITS main committee meeting in Washington during the A.S.T.M. Committee Week, Committee C-16 on Thermal Insulating Materials celebrated its first decade in the A.S.T.M. family of committees. An interesting history of the committee's first ten years was presented by Charles B. Bradley, of the Johns-Manville Research Center. In this he reviewed the studies which were made prior to the organization of the committee and noted the organization meeting, listing the committee's first members. Several of the first members have attended every meeting the committee has held. At the present time the group has over eighty individuals participating in its work, and there are nine subcommittees not including the advisory group. A number of widely used specifications and test methods have been issued and there is much active work under way.

In his historical discussion Mr. Bradley paid tribute to the officers and members including the late J. H. Walker who had served the committee as first chairman and who was later elected honorary chairman and E. T. Cope who was the first secretary and later chairman. A portion of Mr. Bradley's concluding remarks follows: "Quality, not quantity, must be the true measure of the merit of the result of our labors. Also, the standards now on the books of the Society cannot adequately measure the effort which has been put into the

K. M. Ritchie, Secretary, Committe C-16

Charles B. Bradley

H. C. Dickinson, National Bureau of Standards, *left*, and Ray Thomas, Chairman of C-16.

activities of Committee C-16 by its members. Nevertheless, just on the basis of the number of standards produced, we feel that we need not be ashamed. We face the future with the firm intention to carry on the activities of our committee so as to produce the best results, in the broadest possible terms, for American industry."

Shipping Container Committee Meets in Cleveland

THE Spring Meeting of Committee D-10 on Shipping Containers was held at the Hotel Statler, Cleveland, Ohio, on April 26 and 27. Many of the committee members were in Cleveland to attend sessions conducted by the Packaging Division of the American Management Association. An attendance of 41 was reported at the main D-10 meeting, which included seven visitors.

Several recommendations were presented, one of the most significant being a long-awaited list of definitions. These will be referred to the Society for approval. Another item, which has had considerable study by the committee, was the recommendation for submittal to the Society of a vibration test method. Several proposed new standards were recommended for letter ballot of the committee including a drop test for cylindrical containers, a method of test for the penetration of liquid into containers and a method of test for the water-vapor permeability for containers other than shelf size packages.

Work is in progress on test methods for large-size containers or crates and a special subcommittee has been appointed to make a study of test methods for localized impact, such as snagging and puncture. The Subcommittee on Performance Standards outlined an initial program consisting of the following steps: (1) classification of various articles being shipped, (2) the evaluation of the different kinds of shipments used, and (3) the determination of the requirements in each standard test method, such as number of falls in the revolving drum or number of drops in the drop test, which might equal or represent transportation hazards. It is with this information that the subcommittee hopes to eventually establish performance standards for use in the shipping container field.

The Subcommittee on Interior Packing indicated considerable activity, including the completion of a bibliography containing 50 references, a presentation of a proposed list of 75 definitions, a statement that existing standard test methods for shipping containers appear to be adequate for use in testing interior packing, and a preparation of a list of 41 materials used for interior packing purposes.

This very successful meeting of Committee D-10 closed with an interesting talk presented by R. A. Mantz, International Harvester Co. whose subject was "Research in Container Design and Its Relation to Materials Handling."

Active Meetings of Committee D-12 on Soaps and other Detergents

SOME sixty members and visitors attended the annual meeting of A.S.T.M. Committee D-12 on Soaps and Other Detergents held on March 23 and 24 in the Park Central Hotel in New York City. A luncheon meeting of the main committee was held on March 24, following which the reports of the subcommittees were presented.

The Subcommittee on Soap Tests approved the following editorial revisions in the Methods of Sampling and Chemical Analysis of Soaps and Soap Products (D 460): (*1*) Correct the factor in Section 42 for converting SiO_2 to sodium silicate to read 1.318 instead of 1.308; (*2*) Correct the factor in Section 41 for calculating borax to read 0.009536 instead of 0.00955; (*3*) Change Section 37 to prescribe ethyl alcohol *near the boiling point* as the solvent. This subcommittee, which functions as a Joint Committee on Soap Analysis with the American Oil Chemists Society, is undertaking a review of the Federal specifications covering analysis of soap and will recommend such changes as may be necessary to bring the Federal specifications and the A.S.T.M. and A.O.C.S. methods into agreement.

The Subcommittee on Dry Cleaning reported that work is being continued toward developing an accurate method of determination of moisture content of dry cleaning detergents. Within the coming year this subcommittee may complete a performance test for dry cleaning detergents.

The Subcommittee on Special Detergent Tests recommended for publication as tentative a method for the analysis of borax. Methods for the analysis of sodium bicarbonate and for the determination of sodium bicarbonate in soda ash are in preparation and should be completed during the coming year.

The Subcommittee on Physical Testing has been conducting cooperative work on a canvas-disk wetting-out test. The method, which has been tested by ten laboratories, is not felt to be quantitative as written and studies are therefore being continued. This subcommittee is also studying the Draves-Clarkson test and foaming and detergency tests.

The Subcommittee on Metal Cleaner Tests has in preparation revisions of the Tentative Method of Total Immersion Corrosion Test of Water-Soluble Aluminum Cleaners (D 930) intended to clarify the present printing of the methods. In Section 34 of Methods of Chemical Analysis of Industrial Metal Cleaning Compositions (D 800) an editorial revision of the requirements for xylene in the distillation test for water was approved which prescribes the use of nitration grade xylene. A corresponding change was also approved in Section 12 of Methods D 460. Methods for the determination of surface and interfacial tension of solutions of surface-active agents are in preliminary form and will be completed during the coming year. Also nearly completed are corrosion tests for metals other than aluminum.

The Subcommittee on Soap Specifications recommended that the tentative revisions of Specifications for Milled Toilet Soap (D 455), White Floating Toilet Soap (D 499), and Compound Chip Soap (with Rosin) (D 690) be adopted as standard. This subcommittee also expects to complete preparation of specifications covering (*1*) solid, low-titre and medium-titre soap, and (*2*) granular or chip low-titre and medium-titre soap.

The Subcommittee on Synthetic Detergent Specifications has been unable to complete the preparation of specifications for these materials for the same reasons as given above for the delay in preparing standard methods of testing synthetic detergents. It is realized that this is an important field and work will be continued as soon as adequate information is available as to what the specification requirements for such materials should be.

The Subcommittee on Nomenclature and Definitions recommended the adoption as standard of the Definitions of Terms Relating to Soaps and Other Detergents (D 459). These definitions have been extensively revised since they were first issued in 1937 and are now felt to provide a very complete and satisfactory set of definitions relating to soap and detergents.

Cathode Nickel

Abstracts of Technical Papers

At the recent convention of the Institute of Radio Engineers in New York on March 24, several members of the Cathode Section of Subcommittee VIII on Radio Tubes of A.S.T.M. Committee B-4 on Electrical Heating, Resistance, and Related Alloys presented papers discussing some of the work of the section and a report on an investigation of European practice.

The first of these papers was presented by R. L. McCormack of the Raytheon Manufacturing Co. and outlined the story of the work of the Diode Subsection of which he is chairman A second paper was presented by Mr. J. T. Acker of the Western Electric Co. and gave the story of the Data Subsection of which he is chairman.

Another paper presented at the same meeting by T. H. Briggs (chairman of the Cathode Section) reported on a trip to England, France, Holland, and Germany in the Fall of 1947 made by Mr. Briggs and A. M. Bounds, both of whom are with the Superior Tube Co.

These papers will be published in the *I.R.E. Journal* but as they are of direct interest to many A.S.T.M. members who may not see the papers in that publication, abstracts of the three papers are given below.

ABSTRACTS

A Standard Diode for Radio Tube Cathode-Core-Material Approval Tests

By Robert L. McCormack

The role played by core material in the emission of electrons from oxide-coated nickel-base cathodes has been the subject of considerable conjecture and controversy almost since the discovery of the oxide-coated cathode. Various hypotheses proposed to account for the apparent superiority of one core material have not always been in complete agreement chiefly because of the complexity of the emission phenomena. While the mechanism of emission is not clearly understood, good oxide-coated cathode tubes have been produced for many years. The industry, however, has been aware of the possibility of a low emission epidemic and has been critically examining the cathode material as the obvious first place to look for trouble. It has been standard practice to check performance of each new melt of nickel before accepting it for production use.

The conditions under which the test was made, the acceptance criteria and the interpretation of test results have varied widely from company to company and even from division to division of the same company. The normal time elapsed before obtaining melt approval has been about three months and if some companies accepted it and some rejected the melt (as was not uncommon) the suppliers were faced with a very perplexing situation. To correct this unhappy situation, the Cathode Section in Subcommittee VIII of A.S.T.M. Committee B-4 was organized with chemical, metallurgical, diode, and data subsections. **It is with the work of** the Diode Subsection that this paper is concerned.

The Standard Diode Approval Test Method:

The primary purpose of the diode structure, as conceived by the committee members, was to provide a standard tool for the investigation of the various cathode material melts supplied for production use. A secondary purpose of the diode was to investigate the effect of variations in the additives in the nickel melt and variations in processing and testing methods. It was agreed that the structure should consist of standard receiving tube parts and the committee finally evolved what was a miracle in economy—the parts having been obtained from obsolete receiving tube dies (see Fig. 1).

The diode melt testing method has several advantages over the multi-tube test method. It is a simple structure, easily produced, and standard uniform parts have been made available to all companies. The vendor produces only one size cathode cylinder for melt approval and the comparison melt that has been set aside provides a uniform standard. Thus, standardization of design, processing techniques test methods and controls is possible and changes found to improve the accuracy or reliability of the test method by one laboratory can be applied readily in other laboratories. The diode testing was started as a supplement to the multi-tube test method but with progress over the past two years, in at least one case, has now supplanted it.

Two years' experience with the diodes has made it plain that additional design and processing controls were necessary. Parts tolerances had to be tightened. Test methods had to be revamped. Standards for cathode spray manufacture and application and for parts processing have been developed.

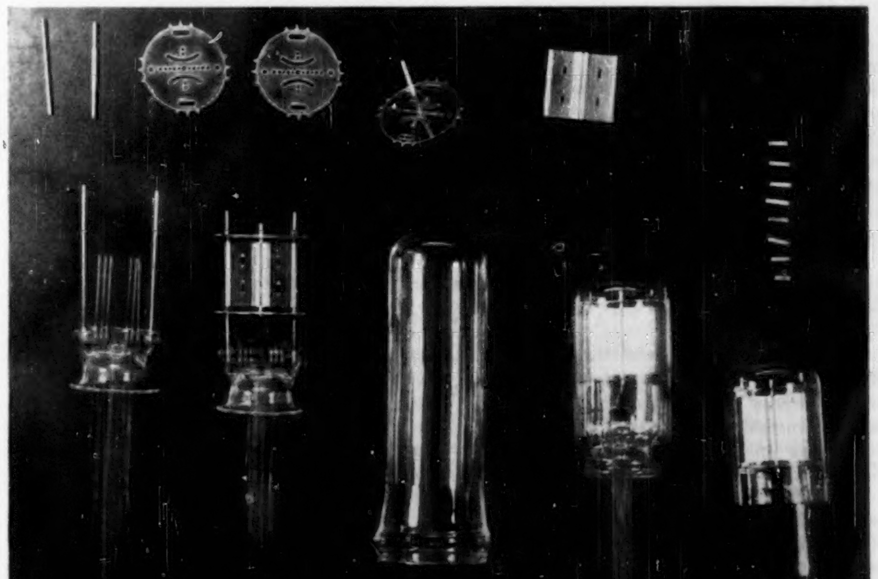


Fig. 1.—The Standard Diode

The completed diode is shown in the lower right with various parts shown above and the assembly operations to the left.

Testing of the Standard Diode:

In the testing of diodes the committee had to feel its way. The Joint Army-Navy emission test for receiving tube types was first tried. Variations in emission current were observed from tube to tube, caused largely by variations in tube geometry and the test proved to be a simple "go-no go" proposition and was deemed inadequate. Three methods of checking emission are used by the committee. The first of these is to plot a full cathode temperature *versus* emission current curve at a fixed 40-volt anode potential, noting the position of the "knee" of the curve that is the transition point between temperature limited emission and space charge limited emission. This is taken as a measure of the relative emission capabilities of the cathode. It gives an indication of how the cathode will perform under d-c. drain conditions simulating the maximum drain conditions a receiving tube would receive in actual service. In the second method, more recently developed, data have been taken under low field conditions with an anode potential of 4.0 volts. This low field emission test is thought to give primarily an indication of the activity of the cathode surface. The third type of test uses pulse emission techniques. This has one significant advantage over the two static emission tests mentioned previously in that it permits examination of temperature limited emission at rated cathode temperatures without exceeding the rated anode dissipation of the diode. The emission current observed under pulse conditions is a function of the resistance of the coating and interface.

Life Test Methods:

As the manufacturer is interested not only in initial characteristics but also in the performance of tubes against time under operating conditions, the Diode Committee has incorporated a life test as part of the melt approval procedure. The conditions of this test have been modified as data were accumulated under various drain conditions. The present standard life test consists of a minimum of 500 hr. operation at rated heater voltage and a drain of approximately 100 ma./sq. cm. In addition to the static life test, a few diodes have been life tested under pulsed conditions by the Camp Evans Signal Corps Laboratory.

Results of Diode Tests on Various Melts of Core Materials:

In the early stages of the diode program the committee was anxious to find some melts of core material which exhibited widely differing emission characteristics so that the Chemical and Metallurgical groups could be given something concrete on which to start. In casting about for such material, they came upon a small quantity of tubing in the diode size of unknown origin labeled cryptically WR5160 which, when tested on the diode, produced startlingly poor emission characteristics. Chemical analysis of this melt showed it to be an extremely pure nickel with low reducing agent content which might have been insufficient to produce enough free barium to mantain emission. The low magnesium and silicon content indicated that the nickel might have been incompletely deoxidized. Lead and zinc were present in larger quantities than is common in cathode nickel. The presence of these elements suggested this nickel may have been produced electrolytically. Unfortunately, sufficient material was not available for metallurgical analysis or for total oxygen content determination, and work on this material had to be terminated.

With Melt 66 being used as the standard of comparison, approval of new melts and compilation of data proceeded from Melt 60 until Melt 71 was reached without any melts being startlingly above or below this standard. Early tests on Melt 71 based on the 40-volt static emission test previously noted indicated in the tests made by three companies that this melt was somewhat inferior in performance to the melts tested previously but a fourth company found it better. As it was found that the fourth company had obtained samples from a later drawing of this material surface contamination of the earlier samples was suspected. A second series of tests run on specially cleaned samples brought the results more in line and a new sample of Melt 71 tested by the companies was found better than the comparison melt in all cases.

At the time these results were obtained, the pulse and low field emission tests had not been incorporated in the subcommittee's testing procedures. More recently a log-log plot of pulse emission *versus* low field emission on the same tubes has shown an apparent straight line relationship between these two characteristics.

Conclusions:

An inventory of the results achieved in the three years of diode testing shows a very favorable balance. Correlation between test results reported by the various plants testing cathode core material melts has shown marked improvement with diode testing. The study of testing methods has brought about a better understanding of the effects of tube design and processing upon emission. This has resulted in improved tube to tube and test to test uniformity. Work on processing, testing and material standards has been started and in most cases completed. The effects on emission of various additives in core materials, and the significance of modifications in core material melting, drawing and cleaning methods have been evaluated. In some cases, the cause of poor activity in a particular test sample has been isolated.

Full understanding of the emission problem still seems remote, but because active interest in the problem has been aroused and crystallized into a joint effort, the immediate goal, that of a satisfactory melt approval test method, now seems attainable.

Testing Cathode Materials in Factory Production

By J. T. Acker

As the previous paper on the evolution of the standard diode indicated, conditions under which the vacuum tube manufacturers have been testing cathode nickel can aptly be described as chaotic. Each company has accepted or rejected a new melt on the base of final test results and life performance of the metal in tubes of current production compared with the same tubes using a previously accepted melt. An idea of the variety of tubes used is shown in Fig. 2. Comparison of industry-wide results were contradictory and full of inconsistencies. To correct this condition and to improve the understanding of thermionic emission phenomena, a new section of Subcommittee VIII of A.S.T.M. Committee B-4 was formed in January, 1945.

The Data Subsection, whose activities this paper reports, is interested in coordinating the methods of test and interpretation of results so that an industry-wide evaluation of each melt may be made to compare with evaluations based on the use of simple and much cheaper diode structures and ultimately chemical and/or metallurgical tests on the nickel.

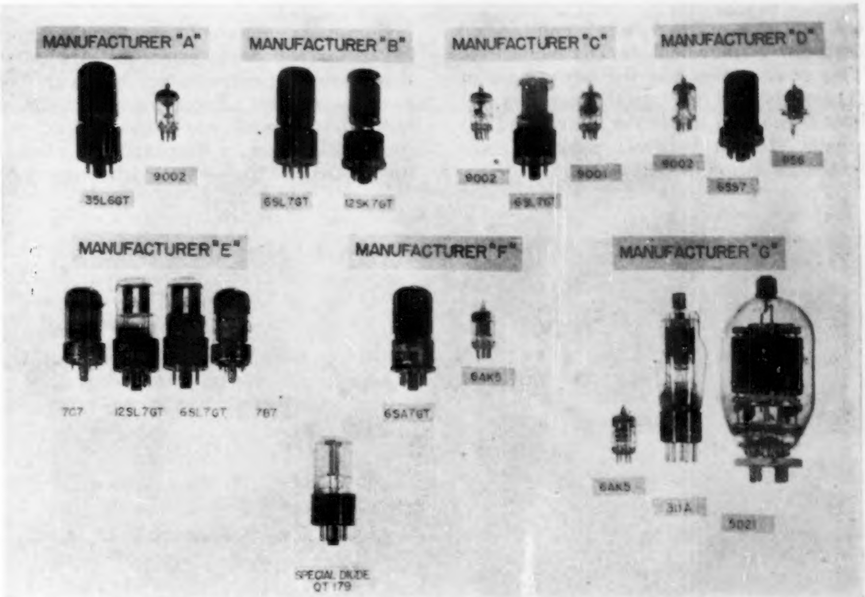
The first step was to reduce the factory prove-in tests to a common denominator and two hundred pounds of Melt 66, a 220 grade nickel, which had apparently given normal test results, were set aside as the basis of comparison for all in the industry. Sample cathodes from this melt are sent along with cathodes from each new melt and prove-in runs are made from the new melt and Melt 66 simultaneously under dentical processing conditions.

The second step was to have the participating companies choose similar types of tube for the prove-in factory runs (tube varieties formerly used are shown in Fig. 2). The industry evaluates the melts on the basis of initial shrinkage, initial tube characteristics, and life performance tests. In each category the comparison is expressed as a ratio of results for the test melt to the control melt. In arriving at an over-all figure of merit, shrinkage and life are weighted twice as important as initial tube characteristics.

For the past three years the Data Subsection has been tabulating such results reported to it by the industry. There are still instances where one company obtains the best results for a given melt in a particular comparison and another company finds it the poorest. The maximum variations for a given melt are of the order of 25 per cent. Despite these differences the over-all figure of merit seems to be giving a true picture of the quality of cathode nickel.

It is recognized that the cathode sleeve is perhaps of secondary importance to the

Fig. 2.—Tubes Used for Prove-in Tests Prior to Development of Standard Diode shown at Lower Left.



coating applied to the cathode and the processing of the tube. It has been found also that surface contamination of the cathode sleeve may mask the effect of base metal composition on thermionic emission. However, the work of this section has put melt approval tests on at least a semi-quantitative basis and it is felt that a melt substantially different from the usual variety should show a figure of merit higher or lower by several per cent. An instruction manual for factory testing by this method is being prepared in considerable detail so that even better control of factory tests will be made in the future and the results are expected to be more reliable.

European Practice in the Manufacture of Cathodes

By T. H. Briggs

European plants are still handicapped with respect to skilled manpower, machinery, and materials but these physical handicaps have not been a deterrent to progress in thinking.

Nickel Melting and Alloy Composition:

While in the United States six cathode alloys are used in three major classifications of thermionic activity, European practice is to have one, or at most two alloys—generally of slightly different composition for each country. In Europe high-frequency induction melting is generally employed with heats of about 500 lb. and metallurgical problems arising in vacuum-melted heats up to 10,000 lb. such as used here have no European counterpart.

Hot working practices are similar to those in this country. While extrusion of large hot billets into tubing originated in Germany, seamless tubing there now has to be made from sheet deep drawn into cups. Prior to the war, refined European nickel did not contain cobalt and conversion to nickel containing about 0.5 per cent cobalt at first caused concern to electronic engineers but they are now generally agreed that cobalt has no effect upon emissivity of coated cathodes.

Coating Composition and Methods:

Due to lack of variety in base metals, Europeans have obtained differences in emission levels by coating and activation modifications. Many European companies are now precipitating their own carbonates with great emphasis placed on the elimination of even small traces of impurities. As a consequence of the high cost of carbonates, considerable work is being done on cataphoretic coating of cathodes—particularly in Germany and France.

There is agreement that calcium improves adhesion of the coating but usually lowers the emission level. Manual spray methods of coating application are analogous to those used in this country. Coating thickness is frequently only half (1.75 mils) standard U. S. practice (3.0 mils). A machine for cataphoretic coating is sometimes used in Germany and Europeans believe these coating methods have a good future but that optimum coating conditions have not yet been fully determined.

Cathode Activation:

In cathode activation the investigators found little difference from our normal practice. Europeans place emphasis on providing the best possible vacuum prior to and during cathode coating breakdown. The Germans attributed early hour life slumping to gases coming from the parts and from electron decomposition of coating breakdown by-products. Several companies employ a paste getter on the screen grid to remove gas during aging.

Theory and Engineering Programs:

In Europe melts of cathode nickel are generally approved solely on the basis of chemical analysis. Tube prove-in tests similar to U. S. practice are run by two European companies while a third makes such tests when checking new sources of supply or new alloys.

Standard diode tests are made by two of the companies investigated. Testing under pulsed conditions is preferred to d-c. emission. One company claims to have found a linear relationship between d-c and pulse emission using readings obtained at low cathode temperature and low anode pulse voltages. Emphasis is laid on gross errors measured in emission phenomena as a function of cathode heater voltage or wattage input.

One feature, generally found in European cathodes taken from activated tubes, is extremely puzzling. The interface between the coating and the base metal is lighter in color than that found on "normal" and "active" cathodes from U. S. tubes. In addition, this light interface is readily removed, along with the coating, in dilute HCl. The coating, alone, is removed in our tubes. What little work has been done abroad on interface compound compositions agrees with data available in this country. There has apparently been very little research to determine the state in which the minor constituents are present in the cathode alloys.

The theories of emission abroad follow the same general pattern as in this country. That a wide variety of statements on emission theory was found in Europe is not surprising due to a summary of this situation made by a Westinghouse engineer to the effect that: (1) Present theory is based on equilibrium considerations which do not always obtain. (2) The role of base metal minor constituents is still uncertain. (3) Interface studies have been made only recently. (4) The long-established barium monolayer theory is just being discarded.

Cathode Constructions:

In Europe seamless tubing is used almost entirely although lockseam cathodes are well known and a few are used. Wall thickness of sleeves is usually 0.003 or 0.004 in. in Europe compared with the 0.002 and 0.0025 standards here. This only affects heating time and rigidity, and

not emission. The use of pointed-end cathodes is prevalent in German tubes. This construction has the advantages of (1) low thermal loss into the top mica, (2) heat is confined inside the sleeve, and (3) greater spacing between cathodes gives better insulation in the spacers.

Summarizing these findings, the author states that European practices and thinking concerning cathodes are basically the same as our own. Economic conditions—both normal and war-induced—lead to some differences. Emphasis is placed upon purity of the coating carbonates and economical methods of application. The cathode base metals are higher in magnesium content than all except one U. S. alloy. The difference in interface color and permanence is worthy of extensive study, as it may be important in pulsed applications.

Actions on Standards for Bags, Fuel Oil, Plastics

On March 18 the Administrative Committee on Standards, acting for the Society, approved the four actions affecting standards on plastics, as noted on the accompanying table, and on April 7 approved the revised fuel oil specifications and the new drop test for bags. A few notes on these actions on the recommendations from A.S.T.M. technical committees, follow:

Plastics:

The new Test for Apparent Density and Bulk Factor of Non-Pouring Molding Powders (D 954) is intended for the determination of the fluffiness or bulk of molding powder that does not readily pour through the funnel (D 392, Fig. 1) used in determining apparent density of freely pouring molding powder. The determination is made by measuring the volume occupied by a known weight of the loose powder. The bulk factor is the ratio of the volume of any given quantity of loose molding powder to the volume of the same material after molding. By suitable transformation of this ratio, it will be found that the bulk factor is also equal to the ratio of the molding powders, calculated as follows: B.F. = sp. gr./apparent density.

The revised test for relative mobility involves the use of a more accurate title and the use of the phrase "molding index" instead of mobility, which is considered more accurate, to avoid confusion and misinterpretation.

The revisions in the Test for Specific Gravity of Plastics (D 792) comprises the inclusion of the statement on the significance of the test for specific gravity and refinement in the requirements for test specimens, and the inclusion of formulas for calculating specific gravity when water is used as the immersing medium and when kerosene is the immersing medium.

The specifications for nonrigid ethyl cellulose are being withdrawn since it was believed there are no peacetime applications for the materials. They were written in 1942 to provide a standard by which ethyl cellulose compositions could be selected for wartime applications in the nonrigid field. These were used in place of rubber or other elastomers in certain applications, but as the synthetic rubber program developed their use became negligible.

Drop Test for Bags:

The new tentative method of drop test for bags was developed through the work of Committee D-10 on Shipping Containers. The method covers procedures for making drop tests on loaded shipping bags, for measuring the ability of the bag to withstand handling, or for comparative evaluation of various bag constructions. The procedure is suitable for testing all types of commercial shipping bags. Requirements are given on the apparatus needed, on test specimens and number of tests, conditioning, general procedure, report, etc. In order for the results of the test to be of most usefulness a number of rigid requirements have been incorporated such as the specified sequence of drops, the height (4 ft. unless specified differently), the use of a hazard, and the point at which failure is considered to occur.

Revised Fuel Oil Specifications:

The revised specifications for fuel oils carry the A.S.T.M. designation, D 396–48 T. The five grades of fuel oil for various types of burning equipment are covered and the text of the specification notes general requirements, refers to the methods of testing with detailed titles for each test, and Table 1 gives the detailed requirements with which the grades of fuel oil must conform.

The revised specifications have resulted from very extensive consideration in Committee D-2, specifically its Technical Committee E on Burner Fuel Oils. This committee has had under way in cooperation with units in the burner industry extensive series of tests on the burning characteristics of the fuel oils. The data resulting from these tests were carefully considered in agreeing on the new requirements.

Actions by A.S.T.M. Administrative Committee and Standards, March and April, 1948

New Tentatives

Methods of:

Test for Apparent Density and Bulk Factor of Non-Pouring Molding Powders (D 954–48 T)
Drop Test for Bags (D 959–48 T)

Revision of Tentatives

Specifications for:

Fuel Oils (D 396–48 T)

Methods of:

Test for Measuring the Molding Index of Thermosetting Molding Powder (D 731–48 T)
Test for Specific Gravity of Plastics (D 792–48 T)

Withdrawal of Tentative

Specifications for:

Non-Rigid Ethyl Cellulose Plastics (D 743–44 T)

DISTRICT ACTIVITIES

Interesting A.S.T.M.-S.A.E.-A.S.M.E. Joint Meeting in Los Angeles

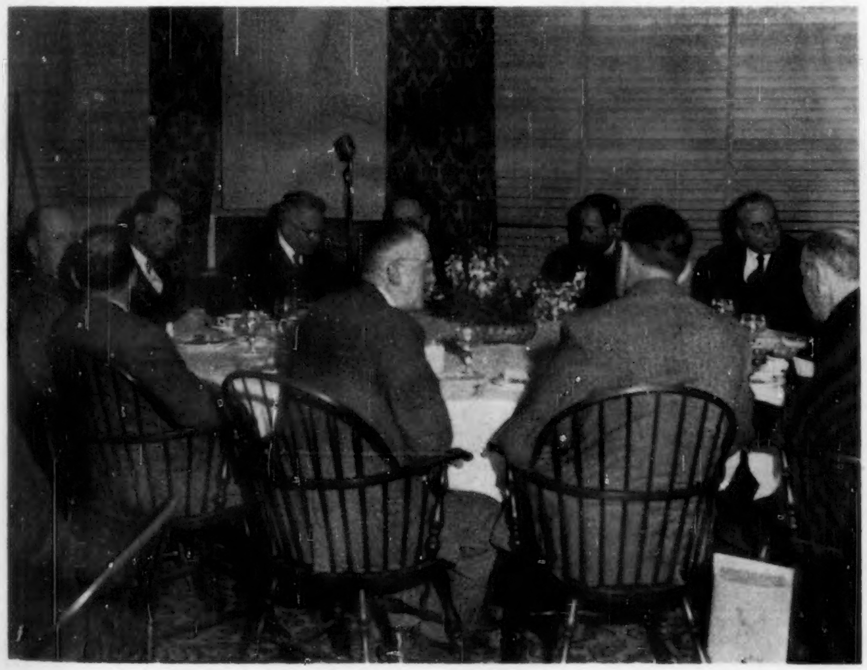
THE MEETING arranged by the A.S.T.M. Southern California District on the occasion of the recent visit of President Boyd and Executive Secretary Warwick to that area was a jointly sponsored affair with the Los Angeles sections of the Society of Automotive Engineers and The American Society of Mechanical Engineers.

T. A. Boyd, President of the A.S.-T.M., delivered his "Research on Materials and Mechanisms" paper, S.A.E.'s technical chairman C. E. Emmons humorously introduced the greats and past greats of both societies present and J. Frank Duryea, in person, related the wartime difficulties of getting his third Duryea in running condition for the 50th Anniversary of the memorable 1895 Chicago-Evanston horseless carriage race.

It was fitting that S.A.E.'s Wellington Miller, famous for his collection of horseless carriages and historical automotive equipment, should introduce Mr. Duryea. "The first thousand Duryeas were turned out with less effort than it took to recondition Number Three for this race," Duryea said. Beside engine casting and fitting difficulties, historical accuracy required the services of a wheelwright and a leather dashboard finisher. Regarding these two, who were available for week-end work only—"two men were required to keep one 'right side' up, as he was some 90 years old, and a third to keep the other out of jail," Duryea related. After surviving valve trouble and a broken connecting rod on race day, the machine made the starting line on time and has spent the remainder of its "mechanical career" in the Smithsonian Institute. By way of comment on modern passenger design, he opined that the industry could grant two boons by eliminating chrome glare and by moving the windshield farther away from the driver. In concluding, Mr. Duryea praised the S.A.E. and other societies for carrying on the tradition of scientific progress.

There were about 150 present when C. E. Emmons of the Texas Company Vice-Chairman of both the Southern California sections of A.S.T.M. and S.A.E., introduced Messrs. Warwick, who spoke briefly, and President Boyd. Mr. Emmons referred to Mr. Boyd's work as co-discoverer of the anti-knock effects of liquid compounds of lead which was perfected just 25 years ago. Portions of Mr. Boyd's address are printed elsewhere in this BULLETIN. R. B. Stringfield, Chairman, and H. W. Jewell, Secretary, of the A.S.T.M. Southern California District, participated actively in planning and arranging this joint meeting.

J. Frank Duryea and President Boyd

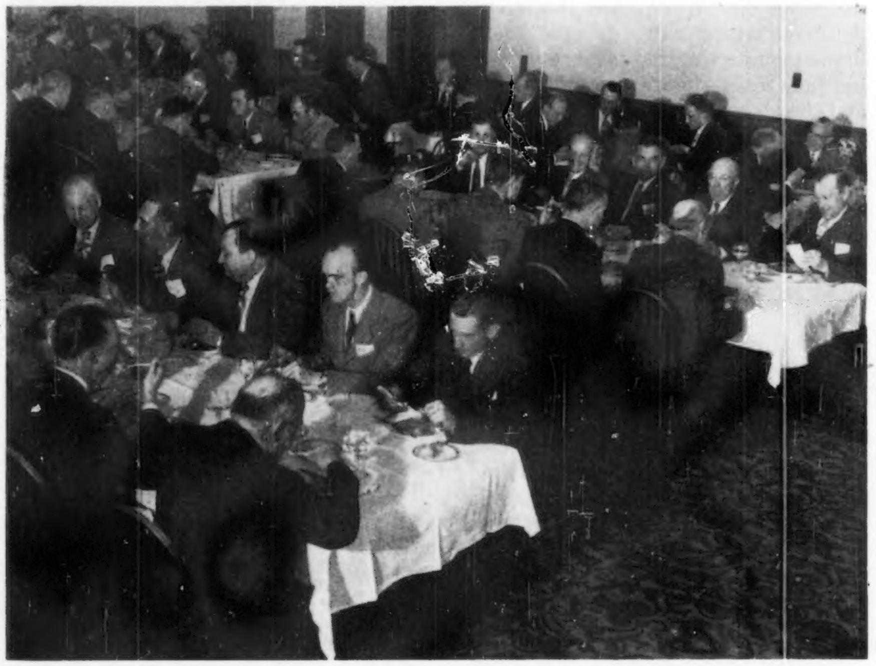


Head Table at The Northern California Meeting

A.S.T.M. Officers at Joint Meeting of Northern California A.S.T.M. and A.S.M.E. Members

PRESIDENT T. A. Boyd, and Executive Secretary C. L. Warwick were present at a joint meeting of the Northern California District of the Society and San Francisco Section of The American Society of Mechanical Engineers, held on Thursday, March 25, at the San Francisco Engineers' Club. About one hundred members attended the dinner and attendance increased to 130 for the technical session which followed the dinner.

Dr. A. G. Cattaneo, Shell Development Co., Chairman of the local section of A.S.M.E., opened the meeting at the conclusion of the dinner, introducing the guest speakers. In accordance with A.S.M.E. practice he had each member introduce the party sitting at his right at the dinner table. In this way the members became acquainted with one another.



Dr. Cattaneo introduced Mr. Warren H. McBryde, who presented an A.S.M.E. award to Dr. Stephen P. Timoshenko, Professor of Theoretical and Applied Mechanics, Stanford University, and well-known authority on vibration problems and author of numerous books and technical papers on this and related problems.

At the technical meeting which followed the dinner, Dr. Cattaneo turned the meeting over to Mr. Dozier Finley, local Chairman of the A.S.T.M. who introduced the guest speakers.

Mr. Warwick spoke on the research which is being sponsored by the A.S.T. M., his subject being "Research and Standardization in A.S.T.M."

The principal address of the evening was made by President T. A. Boyd, who spoke on the subject "Research on Materials and Mechanisms." Mr. Boyd's talk was extremely well received by the assembly. His subject included the development of diesel electric locomotives on railroads through the medium of research and also touched on the development of atomic energy through the same medium. Portions of the address which Mr. Boyd presented appear elsewhere in this BULLETIN.

Outstanding Meetings in Cleveland on Research

UNDER the auspices of the Cleveland District there was held at the Cleveland Engineering Society on April 7 a most interesting meeting on the general subject of research, with A.S.T. M. President T. A. Boyd speaking on the subject "Everybody's Doing It Now," and Dr. C. F. Prutton, of Case Institute of Technology, covering the "Value of Research in Industry." These two outstanding leaders covered somewhat different phases of this broad subject. Portions of the address by Mr. Boyd are published elsewhere in this BULLETIN. Dr. Prutton emphasized his topic by citing various case histories based on his extensive experience in the field of lubricants, rubber, and other products. He has been Head of the Department of Chemistry at Case Institute since 1935, and was for several years Chief of the Process Development Branch, Office of the Rubber Director in Washington.

Prior to the meeting there was an informal dinner with the district councilors, speakers, and other guests present. There were about 150 members and guests at the technical session.

District Chairman Arthur J. Tuscany presided at the meeting. Many of the local arrangements were handed by Secretary Ray T. Bayless while Prof. Harry Churchill of Case was responsible for procuring his faculty co-worker, Dr. Prutton.

Dr. C. F. Prutton

Messrs. Boyd and Curtis at St. Louis District Meeting on Research

The St. Louis District held its sole meeting of the year on the evening of April 9, 1948, at the Engineers' Club of St. Louis. T. A. Boyd, President of the A.S.T.M. and F. J. Curtis, Vice-President of Monsanto Chemical Co., were the speakers. Each spoke on the subject of research.

Before the meeting a dinner was held, attended by members of the District Council, guests, and Mr. Boyd.

In his address, Mr. Boyd emphasized the phenomenal growth and increasing importance of research throughout industry. Such growth and importance, however, is relative to the part research has played in the past. As far as the future is concerned, much remains to be done. Another point of interest was that from the practical standpoint research pays dividends and is regarded by many as the best investment. Portions of the address which Mr. Boyd presented appear elsewhere in this BULLETIN.

Mr. Curtis described the organization of research at Monsanto. In the chemical industry obsolescence is a major problem: A compound may be a favorite of the market one day only to be superseded by some other the following day. Hence, research must be going forward constantly. To this end, Monsanto has several, not just one, research staffs, each of which works independently in its respective field, but the work is coordinated by a central committee.

F. J. Curtis

About ninety attended the talks.

Meeting arrangements were handled by the St. Louis District officers: Chairman A. W. Brust, Washington University, and Secretary S. B. Roberts, Robert W. Hunt Co.

Japan Through the Eyes of a Metallurgist, at Pittsburgh Meeting

Two interesting nontechnical talks featured the meeting in Pittsburgh on April 26 sponsored by the Pittsburgh District. E. T. Barron, Chief Metallurgical Engineer (Retired) of the Carnegie-Illinois Steel Corp., and W. W. Wentz, Staff Metallurgist, Aluminum Company of America, who had visited Japan in recent months, were the two speakers.

About 110 members and guests were present at the meeting including about 40 ladies who, it is reported, were much interested in the comments by Messrs. Barron and Wentz. The meeting was held in Mellon Institute Auditorium.

Mr. Barron's remarks dealt mainly with the status of the iron and steel industry. He emphasized the need for importing raw materials and the methods used by the Japanese to conserve and utilize all scrap. At the time of his inspection the steel industry was operating at between 10 and 15 per cent of its prewar capacity and it was questionable as to when a greater capacity could be obtained.

Mr. Wentz's talk was primarly on aluminum production. While he had inspected some other non-ferrous metal plants, he was chiefly interested in the aluminum plants. He commented on the modern production methods that are used and on the complete production of aluminum from ore to the finished material accomplished in Japan. He stated that the most modern and most efficient plant had been completed but not placed in service before the end of the war. His talk was illustrated with color slides showing not only the industrial plants and their present development, but existing conditions in the various cities he had visited.

The Pittsburgh District Council headed by J. J. Bowman, Chairman, and M. D. Baker, Secretary, made all arrangements for the meeting.

← **W. W. Wentz**

E. T. Barron →

Chicago District Arranges Panel on Value of Specifications in Production

Three Papers at A.S.T.M. Session During Chicago Conference

THROUGH the interest of the A.S.T.M. Chicago District, the Society sponsored one of fifty-four panels which had been arranged as the Chicago Technical Societies Council Conference at the Hotel Stevens on March 22–24, inclusive. The A.S.T.M. Panel, T-26, featured discussions by three leaders in their fields on the subject "The Value of Specifications in Production." The titles of the papers and the speakers follow:

- Buying Steel by Hardenability and by Composition Specifications—Harry B. Knowlton, Materials and Standards Engineer, International Harvester Co.
- Development of Modern Alloy for Die Castings—Donald L. Colwell, Sales Engineer, Apex Smelting Co.
- Selection and Control of Plastics—Harvey A. Anderson, Raw Materials Engineer, Western Electric Co.

Synopses of the papers appear below.

The honorary chairman of the meeting was Charles H. Percy, Secretary of the Bell & Howell Co. He introduced the technical chairman with appropriate remarks on the use of specifications in the engineering of motion picture equipment. The technical chairman was J. J. Kanter, of the Crane Co., Chairman of the A.S.T.M. Chicago District Council. D. L. Colwell, Chairman of the District's Program Committee, set up the program for the A.S.T.M. session and followed through on various other matters. G. E. Stryker, District Secretary, also cooperated. The A.S.T.M. District Council participates actively in the work of the Chicago Technical Societies' group and has had a part in all of the conferences that have been held.

Buying Steel by Hardenability and by Composition Specifications

H. B. KNOWLTON, International Harvester Company

THE physical properties, such as hardness and toughness, of many steel parts are produced by hardening and tempering. The response to these treatments depends upon the hardenability of the steel, which in turn is affected by the chemical composition. Consequently for many years steel has been purchased on a basis of chemical composition. It has been found, however, that the *total* composition is of much more importance than the actual percentage of any particular element. About ten years ago Jominy devised a method for testing hardenability of steel directly, rather than depending upon indirect calculations from composition. This method has since been accepted as standard. The testing technique has been covered by A.S.T.M. designation A 255 (End-Quench Test for Hardenability).

During the war, emergency steels were selected on the basis of duplicating the hardenability of the previously used steels. Since then the A.I.S.I. has proposed a scheme of specifying steels on both chemical analysis and hardenability. These specifications permit slightly wider ranges of analysis, so far as individual elements are concerned, but a closer control of total composition and hardenability.

A recent survey made by the S.A.E. Division on Hardenability has shown a general trend in the automotive industry toward the purchase of alloy steel on specifications covering both analysis and hardenability. Over half of the steel users replying to the questionnaire are purchasing steels under the "H" band hardenability specifications. The use of these specifications should eliminate about 3 per cent of the heats of steel which are the lowest in hardenability, and another 3 per cent which are the highest. About 96–97 per cent of the heats will be the same as those previously purchased under specifications for composition. Nevertheless about half of the users have found that the use of hardenability specifications has reduced the number of rejections due to failure to meet minimum hardness specifications. Less trouble in meeting cross-sectional hardness requirements has also been reported. Similarly, difficulties due to distortion and cracking have been reduced.

On the whole, it seems to be evident that the use of "H" band specifications has eliminated the small per cent of heats of steel, which have caused the greatest amount of trouble in the heat-treating department.

Development of Modern Alloys for Die Casting

DONALD L. COLWELL, Apex Smelting Co.

THE die casting industry has enjoyed a phenomenal growth over the past two decades or so. The two principal alloys used are based on zinc and on aluminum. The quantity of zinc used has increased from 10,000 tons in 1923, which was 2 per cent of the total zinc, to 205,000 tons in 1946, which represented 26 per cent of the total zinc for that year.

There are several reasons for this phenomenal growth, and one of these is the development of suitable alloys. A.S.T.M. Committee B-6 on Die Cast Metals and Alloys, organized in 1925, has sponsored a research program which has led to specifications for both zinc and aluminum base die casting alloys which are universally accepted. Die casting manufacturers, zinc and aluminum producers and smelters, and die casting users have cooperated to an extent unique in American industry to bring this about.

Aging tests to determine the effects of time and the elements on various alloys were conducted at a number of different geographical locations on the North American continent and current specifications are largely based on the results of fifteen years' exposure of die cast samples. Details of the effect of these exposures on both zinc and aluminum alloys are presented. These tests prove that die castings produced today from the leading alloys corresponding to A.S.T.M. specifications are a valuable and permanent engineering material in automobiles, household utilities, business machines, and numerous other products.

Chemical and mechanical limits set by the specifications and confirmed by the exposure tests indicate dependable alloys of both zinc and aluminum are in industrial use today. Extensive war uses of die castings were described, and a newly developed automobile engine, die cast of aluminum, was noted.

The author pointed out that the present trend for mass production and labor-saving devices promises an even wider use of die castings and the die casting process in the future. Its success must be based on accurate technical control of materials and process.

Selection and Control of Plastics

H. A. ANDERSON
Western Electric Co.

THE purchase of plastics which are products of the chemical industry known as synthetic resins and products made from resins, has gone through the customary cycle usual for new materials: first, purchases were based on suppliers' product names and the suppliers' statements; next came the purchase of suppliers' products in line with specification requirements; and finally, tailor-made products were developed in accordance with customers' specifications. Tool steels, die castings, and stainless steels have gone through somewhat similar evolutions.

There are numerous analogies between metals and plastics. The thermosetting plastics might be compared with ferrous metals, where there is a maximum volume with ensuing lower costs and maximum strength for resisting impact and wear but involving some difficulties in fabrication. The thermoplastic materials, which can be resoftened by heat, might be compared broadly to the non-ferrous field where the temperature for working is lower and fabrication is somewhat more economical and there is a wide variety of materials.

Plastics must meet rather wide demands, for example relatively short life where there may be anticipated numerous replacement parts and considerable maintenance, extending to such fields as railroad, utility and communications, in-

cluding telephones, where long trouble-free life with low cost maintenance is required.

The speaker gave examples from the telephone equipment field of extensive use of both thermosetting and thermoplastic materials, covering both molding compounds and casting resins and wrought plastics.

Fundamentally there are three reasons why plastics find a growing use in the telephone plant. These might be mechanical strength and resistance to wear or flow resistance; or, their properties as electrical insulators; or economical manufacturing and pleasing appearance.

The speaker's company's specifications in general are based on A.S.T.M. standards, the Bell System having cooperated in the Society's work for over thirty years. The Society has built up a great backlog of testing methods, the use of which permits controlled appraisal of properties of competing materials and permits supplier and customer appraisal of quality by common standards and competitive buying without jeopardizing of product quality. Each specification contains scope, requirements, molding of specimens, methods of test, sampling and packing requirements. Most thermoplastic molding compound specifications have specified compression-molded specimens for tensile, compression, flexural, impact, flow, and electrical tests but tendency now with increased use of injection molding is to use injection-molded test specimens.

A.S.T.M. District Areas Defined—Several Expanded

The accompanying map shows the areas of the various A.S.T.M. Districts as established by the Administrative Committee on District Activities in cooperation with the respective District Councils. While the various boundaries may be subject to some modification, in general they will remain as shown on the map.

For some time the Administrative Committee, which is responsible for administrative and coordination of district activities, has felt it desirable to bring more of the membership into the districts and accordingly there has been a considerable expansion, particularly in some of the midwest areas. It will be noted that most of the northeast and north central portions of the country are covered, and a high percentage of the A.S.T.M. membership is now included in the districts. A recent count would indicate that about 85 to 90 per cent of the membership in the United States is included in the thirteen districts that have been established.

The most recent district, the Ohio Valley, has not yet been formally organized but a council *pro tem* has been appointed and organization is pending.

When the 1947 Year Book was issued late in the fall, the new district areas were anticipated and the Year Book indicates by key numbers in which districts most of the members are located.

The following arbitrary key numbers indicate the respective districts and the approximate number of members and committee members are noted.

New York (D 1)	1670
Philadelphia (D 2)	830
Pittsburgh (D 3)	520
Cleveland (D 4)	425
Chicago (D 5)	1050
Detroit (D 6)	480
Southern California (D 7)	215
Northern California (D 8)	150
St. Louis (D 9)	210
W. New York-Ontario (D 10)	330
New England (D 13)	525
Washington (D 14)	620
Ohio Valley (D 15)	300

With the exception of Washington, D. C. these key numbers are the same as used in the Year Book and are the ones which appear on the A.S.T.M. mailing plates. However, the Washington No. 12 has been changed to 14 and the new Ohio Valley is assigned No. 15 because Nos. 12 and 13 were reserved by our printer for mailing classifications. While the Year Book indicates that Southwest Ohio was in the Cleveland District, this will, of course, be changed in the next Year Book.

Map published through the courtesy of the Hagstrom Co., Map Makers, Publishers, Lithographers, New York. This company does much of the re-drawing and art work on drawings used in A.S.T.M. publications.

Gas Turbine Materials to be Subject of Joint Meeting with Canadian Engineers

THE subject of materials for gas turbines is to be covered by Dr. R. B. Gordon, Manager of Metallurgical Development Department, Westinghouse Electric Corp., Pittsburgh, at a meeting in Niagara Falls, Ontario, on May 27. This meeting is sponsored jointly by the A.S.T.M. Western New York-Ontario District and the Niagara Peninsula Branch of the Engineering Institute of Canada. T. L. Mayer, Buffalo Public Library, and O. W. Ellis, Ontario Research Foundation, Toronto, the Chairman and Vice-Chairman, respectively, of the A.S.T.M. District, developed plans for the meeting some time ago, cooperating with officers of the Canadian society in particular R. A. Coombs, of the English Electric Co., St. Catherine's, who is Vice-Chairman of the Niagara Peninsula Section.

Dr. Gordon has been associated with Westinghouse Laboratories for almost ten years, first in the Research Laboratories, and for the past several years working on materials for high temperature and such service.

Research in Industry

WHEN one attempts to present concisely an adequate evaluation of a book such as this, prepared by a group of outstanding authorities in their field functioning as a team under a capable editor-in-chief, he is confronted with a real problem. He can always resort to the bald statement that the best way to appreciate this book is to purchase a copy and study it, with assurance that there will be almost certainly full value received for the investment. Nevertheless some brief description is desirable.

Leading members of the Industrial Research Institute, which group has been steadily growing since it was fostered by the Engineering and Research Division of the National Research Council, prepared the various chapters of this most interesting publication. Dr. C. C. Furnas, Director of Cornell Aeronautical Laboratory, widely known not only for his capable work but for his facile pen, was the editor. The objectives of the volume are the same as for the Institute itself, namely, to promote more effective organization, administration and operation of industrial research, to stimulate a better understanding of research as a force in our national activities, and to promote high standards in the field of industrial research. Since chapter headings are the best means of outlining a publication, they follow:

I. The philosophy and objectives of research in industry.
II. The research laboratory as an operating department of the company
III. Development
IV. The research director's job
V. Organization charts in theory and practice
VI. The research program
VII. Selecting projects for research
VIII. The research budget
IX. Research reports
X. Characteristics of the research man and the research atmosphere
XI. Qualifications, training, aptitudes and attitudes of industrial research personnel
XII. Procurement and selection of research personnel
XIII. Salary policy
XIV. Personnel policies and personality problems
XV. Professional growth of the research man
XVI. The location, design, and construction of a modern research laboratory
XVII. The tools of research: Instruments and supplies
XVIII. The research man's helpers; Service personnel and facilities
XIX. Translating research results into new products and factory procedures
XX. By-products of research
XXI. Evaluating the results of research
XXII. The research director's responsibility in determining the company's patent policy
XXIII. Pattern of collaboration between the research department and the patent department
XXIV. Licenses, royalties, and patent pools
XXV. Relations with the public and government
XXVI. Relations with the educational system
XXVII. Relations with other firms and industry
XXVIII. Research in America and Europe
XXIX. Goals and problems for the future

Most of the chapters include selected references, and much of the information and data are condensed in readable charts and tables. An appendix of 18 pages lists additional references, classified according to topics covered.

In his introductory chapter on the philosophy and objectives of research in industry, Dr. Furnas admits that research cannot be defined in any universal, acceptable manner, but does indicate there is good agreement that "research is the observation and study of the laws and phenomena of nature and/or the application of these findings to new devices, materials, or processes, or to the improvement of those which already exist." The concluding chapter by Paul D. V. Manning answers the question "What is the goal of all Research?" in this fashion: "It is certainly the development of better ways of living in this universe of which we are a part—not for just a few but for all." In between these two chapters is a wealth of information and data and opinions that should be of intense interest and of real help to everyone concerned with research, no matter of what kind or in what fields it may be. There are many well-selected charts, tables, and forms which supplement the text. The Institute should be congratulated on sponsoring this publication. Copies can be obtained from D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y. at $6.50.

British Standard Methods for Testing Petroleum and Its Products

THE Ninth Edition of the Compilation of "Standard Methods for Testing Petroleum and Its Products," as issued by the British Institute of Petroleum, has just been received. In addition to listings of the personnel of the Institute's Standardization Committee and a rather extensive report of the committee, the book gives the 122 methods issued under the Institute's auspices. Many of these are closely parallel or identical with A.S.T.M. standards as sponsored by Committee D-2. In fact, the Institute's group and D-2 are in constant contact. New methods included for the first time cover the following: Chlorine in Lubricating Oil, Knock Rating of Aviation Fuels (Rich Mixture), Lead, Copper and Iron in Lubricating Oils, Oil Separation on Storage of Grease, Spectrographic Analysis of Inorganic Constituents of Ashes. Revised methods cover the following: Corrosion Test for Lubricating Greases (Copper Strip), Diluent Content of Crankcase Oils (Diesel Fuel Diluent), Distillation of Cutback Bitumen and Road Oil, Ignition Quality of Diesel Fuel, Knock-Rating of Aviation Fuels (Weak Mixture), Knock-Rating of Motor Fuel, Penetration of Greases and Petroleum, Saponifiable Matter, Smoke-Point, Unsaponifiable Matter in Drying Oils. With a detailed subject index and two tables of contents, one an alphabetical listing, the other a numerical listing, this 670-page book in heavy paper cover, page size 5½ by 8½ in., can be obtained from A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa., at $6.75 each.

For those who use this British publication regularly it is of interest to note that the Institute does not plan another edition until October, 1949, when an exhaustive new editing job will have been completed.

New Members to April 26, 1948

The following 108 members were elected from March 2, 1948 to April 26, 1948, making the total membership 6401.

Names are arranged alphabetically—company members first, then individuals.

Chicago District

Benjamin Electric Manufacturing Co. Hoyt P. Steele, Executive Vice-President, Des Plaines, Ill.

Case Co., J. I., K. R. Ford, Foundry Superintendent, Bettendorf, Iowa.

Keystone Asphalt Products Co., B. W. Pocock, Director of Research, Sixteenth St., East of State, Chicago Heights, Ill.

Causey, David Frederic, 511 W. Green St., Urbana, Ill. [J]*

Kahn, J. Kesner, Director, Laboratories and Development, Spiegel, Inc., 1061 W. Thirty-fifth St., Chicago 9, Ill.

Kilian, Stanley C., Chief Engineer, Delta-Star Electric Co., 2437 W. Fulton St., Chicago 12, Ill.

Krebs, Charles H., Chief Chemist, Atlas Boxmakers, Inc., 5025 W. Sixty-fifth St., Chicago, Ill.

Schlink, Melvin J., Chemist, Altorfer Bros. Co., Peoria 8, Ill.

Stallmeyer, James Edward, Research Assistant, University of Illinois, Urbana, Ill. For mail: 419 Newman Hall, 604 E. Armory Ave., Champaign, Ill. [J]

Troiano, A. R., Professor of Metallurgy, Department of Metallurgy, University of Notre Dame, Notre Dame, Ind.

Vatter, Albert E., Combustion Engineer, Walter Bledsoe and Co., 310 S. Michigan Ave., Chicago 4, Ill.

Cleveland District

Bousky, Samuel, Supervisor, Product Testing Lab., Jack & Heintz Precision Industries, Inc., Cleveland 1, Ohio.

Krauss, W. W., Research Engineer, Republic Steel Corp., 6100 Truscon Ave., Cleveland 4, Ohio.

Raff, R. D., President, The Diamond Portland Cement Co., Middle Branch, Ohio.

Robinson, T. L., President, The Wel-Met Co., 110 Gougler Ave., Kent, Ohio.

Stier, H. Clay, Vice-President, United Tube Corp. of Ohio, Box 1062, Station "A," Cleveland 2, Ohio.

Detroit District

Dow Corning Corp., T. A. Kauppi, Manager, Product Engineering Dept., Box 592, Midland, Mich.

Cowell, Paul John, Head of Works Laboratory, National Carbon Co., Inc., Fostoria, Ohio.

Detroit, City of, Department of Public Works, George R. Thompson, City Engineer, City Hall, Detroit 26, Mich.

Lofquist, Alexander E., Department Head, R. C. Mahon Co., Detroit, Mich. For mail: 10085 Borgman Rd., Huntington Woods, Mich.

McMaster, Wardley D., Assistant Head, General Chemical Dept., Research Laboratories Division, General Motors Corp., Box 188, North End Station, Detroit 2, Mich.

Peterson, LeRoy L., Chemical Research Engineer, Michigan State Highway Dept., Lansing, Mich. For mail: 407-B Hickory Lane, E. Lansing, Mich. [J]

Sergeson, Robert, Chief Metallurgical Engineer, Rotary Electric Steel Co., 8 Mile and Mound Rds., Detroit 20, Mich.

Winterhalter, J. S., Division Chemical Engineer, Socony-Vacuum Oil Co., Inc., 903 W. Grand Blvd., Detroit, Mich. For mail: 354 N. Main St., Plymouth, Mich.

New England District

Eastern Gas and Fuel Associates, William L. Glowacki, Research Chemical Engineer, 250 Stuart St., Boston 16, Mass.

Haartz-Mason, Inc., Laurence R. Clarke, Factory Manager, 270 Pleasant St., Watertown 72, Mass.

Jameson, Charles F., Chemist, Commonwealth Supplies Co., Amesbury, Mass. For mail: 20 Westland Terrace, Haverhill, Mass.

Shaw, Laurence C., Chief Chemist, Avon Sole Co., Box 785, Avon, Mass.

New York District

Electrolux Corp., F. C. Doughman, Chief Engineer, Forest Ave., Old Greenwich, Conn.

General Electric Co., Air Conditioning Dept., P. S. Kingsley, Metallurgical Engineer, Works Laboratory, 5 Lawrence St., Bloomfield, N. J.

Hercules Filter Corp., George F. Blasius, Vice-President and Technical Director, 204–208 Twenty-first Ave., Paterson 3, N. J.

Stavid Engineering, Inc., S. M. Shackell, Vice-President, 40 Somerset St., Plainfield N. J.

Suter Co., Alfred, Gordon M. Stanton, Manager, 200 Fifth Ave., New York 10, N. Y.

Elliott, William S., Professional Engineer, W. S. Elliott and Co., 261 Broadway, New York 7, N. Y.

Fielding, Harold, Textile Analyst, U. S. Customs Laboratories, 201 Varick St., New York 14, N. Y.

Grivel, A. Charles, Vice-President and Plant Manager, Richmond Screw Anchor Co., Inc., 820 Liberty Ave., Brooklyn, N. Y.

Hirsh, Morris L., Assistant Treasurer, Star Woolen Co., Cohoes, N. Y.

Jonap, R. D., Manager, Technical Service Dept., North American Cement Corp., 41 E. Forty-second St., New York 17, N. Y.

Jones, Arthur A., Supervisor, Engineering Laboratories, Anaconda Wire and Cable Co., Hastings-on-Hudson 6, N. Y. For mail: 18 Olinda Ave., Hastings-on-Hudson 6, N. Y.

Kleindienst, Henry Woodrow, Development Engineer, United Aircraft Corp., Chance Vought Aircraft, Stratford, Conn. For mail: 1248 Hancock St., Brooklyn 27, N. Y.

Lighty, Paul E., Spectrographer, Limestone Products Corporation of America, Lime Crest Research Lab., R. D. 1, Newton, N. J.

Olsen, Willy A. O., Vice-President, Uddeholm Co. of America, Inc., 155 E. Forty-fourth St., New York 17, N. Y.

Polytechnic Institute of Brooklyn, Department of Aeronautical Engineering and Applied Mechanics, Bruno A. Boley, Assistant Director of Structural Research, 99 Livingston St., Brooklyn 2, N. Y.

Safir, Robert, Electronic Development Engineer, Photovolt Corp., 95 Madison Ave., New York, N. Y. For mail: 40 Argyle Rd., Brooklyn 18, N. Y.

Sliz, W. A., Superintendent, Somers Brass Co., Inc., 94 Baldwin Ave., Waterbury 86, Conn.

Todtschinder, Paul, Sales Manager, Koehler Instrument Co., 168-56 Douglas Ave., Jamaica 3, N. Y.

Waters, J. E., Technical Assistant to Plant Manager, General Cable Corp., 26 Washington St., Perth Amboy, N. J.

Northern California District

Kattelmann, Harry R., Manager, Container Laboratories, Inc., 151 New Montgomery St., San Francisco 5, Calif.

McGaw, Stewart H., Student, Stockton Junior College, Stockton, Calif. For mail: 425 Lexington Ave., Stockton, Calif. [J]

Ohio Valley District
(In Course of Organization)

Citizens Gas and Coke Utility, C. R. Holmes, Chief Chemist, 49 S. Pennsylvania St., Indianapolis 9, Ind.

Davis, Edwin H., President, New York Coal Sales Co., 150 E. Broad St., Columbus 15, Ohio.

Fischer, G. Wesley, Metallurgical Engineer, The William Powell Co., Plant 2, 3233 Colerain Ave., Cincinnati 25, Ohio.

Phipps, John B., Testing Engineer, City of Indianapolis, Dept. of Engineering, 402 City Hall, Indianapolis 4, Ind.

Philadelphia District

American Structural Products Co., E. C. Shuman, Director of Research, P. O. Drawer F, Berlin, N. J.

Dillon, J. H., Director of Research, Textile Research Inst., Inc., Box 504, Princeton, N.J.

Gronemeyer, George E., Power Consultant, E. I. du Pont de Nemours and Co., Inc., Nemours Bldg., Wilmington, Del.

Kanavel, G. A., Chief Operations Chemist, Vulcanized Rubber and Plastics Co., Morrisville, Pa.

Lewis, Everett Vernon, Research Associate, E. I. du Pont de Nemours and Co., Inc., Experimental Station, Wilmington, Del. For mail: 109 North Rd., Lindamere, Wilmington 274, Del.

Silberman, Martin H., Technical Director, American Aniline and Extract Co., Venango and F Sts., Philadelphia 34, Pa.

Pittsburgh District

Griffen, John, Coal Preparation Engineer, McNally Pittsburg Manufacturing Corp., Pittsburg, Kans. For mail: 1018 Bessemer Bldg., Pittsburgh 21, Pa.

Nagel, William F., Chief Metallurgist and Inspector, Carnegie-Illinois Steel Corp., Irvin Works, Box 878, Dravosburg, Pa.

Paulin, G. W., Allegheny Ludlum Steel Corp., West Leechburg Div., West Leechburg, Pa.

Pogacar, Charles F., Senior Fellow, Mellon Inst., 4400 Fifth Ave., Pittsburgh 13, Pa.

Prus, Leonard B., Materials and Process Engineer, Westinghouse Electric Corp., Beaver, Pa.

Raab, Fred C., Chief Metallurgist, National Tube Co., Christy Park Works, McKeesport, Pa.

St. Louis District

Beatty, Fred K., Structural Engineer, Black & Veatch, 4706 Broadway, Kansas City, Mo. For mail: Box 8181 Plaza Station, Kansas City 2, Mo. [J]

Southern California District

Patterson, W. R., Chief Metallurgist, The National Supply Co., Box 28, Torrance, Calif.

Southard, John C., Director of Research, Solar Aircraft Co., 2200 Pacific Highway, San Diego 12, Calif.

Washington (D. C.) District

Hampton Roads Testing Laboratories, Witaley R. Mooza, Director, 234–236 Twenty-fifth St., Newport News, Va.

Bekkedahl, Norman, Chemist, National Bureau of Standards, Washington 25, D. C.

Isenhour, John H., President, Isenhour Brick and Tile Co., Box 1249, Salisbury, N. C.

Kingsbury, Henry Lewis, Jr., Instructor in Civil Engineering, North Carolina State College, Dept. of Civil Engineering, Raleigh, N. C. [J]

Todd, Roy H., Manager, Parks-Cramer Co., Box 23, Charlotte 1, N. C.

Western New York and Ontario District

GRONNINGSATER, ANTON, Consulting Metallurgist, Falconbridge Nickel Mines, Ltd., 21 Dundas Square, Toronto 1, Ont., Canada.

HADDOW, F. GORDON, Chemist, Brantford Roofing Co., Ltd., Brantford, Ont., Canada.

MAYCOCK, N. P., Chief Inspector, The Steel Co. of Canada, Ltd., Swansea Works, Swansea, Ont., Canada. For mail: 1926 Bloor St., W., Apt. G, Toronto, Ont., Canada.

SCHNUELLE, LEONARD W., Chemist, Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N. Y.

U. S. and Possessions

ALABAMA POLYTECHNIC INST., Main Library, Auburn, Ala.

ANSON, I. ARTHUR, Vice-President in Charge of Refining, Bell Oil and Gas Co., Box 2007, Tulsa, Okla.

BEATTY, JAMES L., Senior Testing Engineer, Pacific Islands Engineers, Box 2, Station 10, Guam, Guam.

BOHN, A. J., 615 Bona Allen Bldg., Atlanta 3, Ga.

COFFMAN, MARY DRUCILLA, Architectural Engineer, 323 N. Maple St., Harrison, Ark. [J]

GILL, GEORGE M., Works Engineer, Carbide and Carbon Chemicals Corp., Texas City, Tex.

HAZZARD, VIRGIL W., Assistant Chief Inspector, Officer in Charge of Construction, Marianas Area, Bureau of Yards and Docks Contracts, Department of Navy, c/o Fleet Post Office, San Francisco, Calif. For mail: Box 106, Guam, Guam.

LUND, LILLIAN O., Assistant Professor of Home Economics, Textile Research, South Dakota State College, Brookings, S. Dak. For mail: Box 25, College Station, Brookings, S. Dak.

OLSEN, ROBERT C., Professor of Chemistry, Pacific Lutheran College, Parkland, Wash. For mail: Box 796, Parkland, Wash.

SODAY, FRANK J., Research Director, Lion Oil Co., Research Div., El Dorado, Ark.

TECHNICAL LIBRARY, U. S. AIR FORCE, A. J. Winter, Purchasing Officer, Air Proving Ground Command, Eglin Field, Fla.

WALKER, EARL EUGENE, Instructor in Civil Engineering, University of Oklahoma, Norman, Okla. For mail: 443 College, Norman, Okla. [J]

Other than U. S. Possessions

PETROLEOS MEXICANOS, Superintendent, Perforacion Zona Sur, El Plan, Ver., Mexico.

SHAW-PETRIE, LTD., Hugh Miller, Director, North Hillington, Glasgow, S. W. 2, Scotland.

ADUR, PRABHAKAR B., Chemical Engineer, The Associated Cement Co., Ltd., Administration Dept., 1 Queen's Rd., Bombay 1, India.

BAILLIE, JAMES, Chief Metallurgist, Acton Bolt, Ltd., Chase Rd., London N. W. 10, England.

BOCK, CLAUDIO WALTER F., Chemical Engineer, Industria Paulista Vidro Plano Ltda., Av. Sta. Marina 649, Sao Paulo, Brazil.

CAMERON, DOUGLAS A., Technical Superintendent, Turner & Newall (Canada) Ltd., 5600 Hochelaga St., Montreal, P. Q., Canada.

HACAR, BEDRICH, Director, Vyzkumny a Zkusebni Ustav Hmot a Konstrukci Stavebnich, Solinova 7, Prague-De vice, Czechoslovakia.

KARLBOM, N. G. R., Civil Engineer, Svenska Petroleum AB. Standard, Stockholm 7, Sweden.

KLAT, ELIE, Manager, Delta Trading Co., Steel Mill Division, Box 445, 18 Sh. Emad El Dine, Cairo, Egypt.

LEPAGE, L. J. C., Director, Sambre-Escaut, S. A., Hemixem near Antwerp, Belgium.

LOZANO B, ALBERTO GARCIA, Chief of Technical Department, Ofieina de la Industria del Cemento, Bolivar 23 desp. 309, Mexico, D. F., Mexico.

NOBLE, G., Refinery Superintendent, Anglo-American Oil Co., Ltd., Refinery Dept., Fawley, Southampton, England.

NOVA SCOTIA TECHNICAL COLLEGE, A. E. Cameron, President, Halifax, N. S., Canada.

PESENTI, CARLO, General Director, Italcementi Fabbriche Riunite Cemento S. A., via G. Camozzi 12, Bergamo, Italy.

PHILIPPE, HAROLD TRUXTON, Chief Chemist, Australian Cement, Ltd., Seelong, Victoria, Australia.

TRIM, F. A., Engineer, Universal Oil Products Co., 18 Dorset House, Gloucester Pl., London N. W. 1, England.

UNIVERSITY OF ALASKA LIBRARY, College, Alaska.

VINCENTELLI, ANTONIO J., Professor of Highway Engineering, Universidad Central de Venezuela, Escuela de Ingenieria, Caracas, Venezuela. For mail: Norte 5, No. 60, Caracas, Venezuela. [J]

WESTBROOK, A. T., Metallurgist, Research and Development Dept., Canadian National Railways, 360 McGill St., Montreal, P. Q., Canada.

* [J] denotes Junior Member

Personals . . .

. . . News items concerning the activities of our members will be welcomed for inclusion in this column.

James E. Pollak has been appointed Manager, Construction Materials, Southwest Steel Rolling Mills, Los Angeles. He formerly had been an executive of the Pollak Steel Co., Cincinnati.

Ira S. Latimer, for the past twelve years associated with Rotary Electric Steel Co., Detroit, as Metallurgical Engineer, Sales Metallurgist and District Manager at Chicago, has been appointed representative for the Plymouth Steel Co., Detroit.

F. L. LaQue of the Corrosion Engineering Section, Development & Research Div., International Nickel Co., Inc., New York, has been elected President of the National Association of Corrosion Engineers.

J. C. Weaver recently received a new appointment with The Sherwin-Williams Co., being placed in charge of integrating and routing vehicle and resin problems among research, development and production divisions of S-W and its affiliated companies. Dr. Weaver has been associated with the company for eleven years, and, as a member of the staff of the Technical Service Department in Cleveland, most of his work has been devoted to varnish problems, which experience fits him well for his new duties.

David H. Dawson, Director of Sales, Pigments Dept., du Pont Co., Newport, Del., was awarded the honorary degree of Doctor of Engineering by the Drexel Institute of Technology, Philadelphia.

Samuel C. Robison, Technical Director of the Thibaut & Walker Co., Westfield, N. J., was recently elected Vice-President of the company. He also continues as Technical Director.

Alfred E. Roberts has retired from Bull & Roberts, Inc., Consulting Chemists, New York City.

C. H. Wastle, formerly Chief Chemist, Harrisons & Crosfield (Canada), Ltd., Toronto, is now associated with Durham Chemicals (Canada), Ltd., Cap de La Madeleine, Province of Quebec.

W. S. Elliott, formerly of the Materials Section, New York City Department of Public Works, is now a consulting engineer in materials and is continuing with the Engineering Division of the Department where he is working on sanitation studies.

Robert F. Mehl, Head of the Department of Metallurgical Engineering at Carnegie Institute of Technology, delivered the Hatfield Memorial Lecture in London, England, May 5, during the Annual Meeting of the Iron & Steel Institute of England. He spoke on the fundamentals of heat treatment of steel, a subject on which the C.I.T. Metals Research Laboratory has done extensive research during the past ten years. The Hatfield Lecture is sponsored by the Sheffield University, the Royal Society and the Iron & Steel Institute. While in Europe, Dr. Mehl will speak also before the Swedish Metallographers' Society and the Royal Institute of Technology in Stockholm, Sweden.

B. S. Van Zile, formerly with the Hercules Powder Co., Wilmington, Del., is now affiliated with the United States Testing Co., Hoboken, N. J.

Ralph L. Wilcox has been elected Vice-President in charge of Industrial Sales and Engineering for the Gerity-Michigan Corp., Adrian, Mich. He previously served in the capacity of Detroit Divisional Manager for the Company.

H. P. Ferguson, Chief, Refining Control Div., Standard Oil Co. of Ohio, presented a "Review of Current A.S.T.M. Activities" at a Joint Meeting of the Department of Manufacture and the Department of Standards and Tests of the National Petroleum Association, at the Association's Annual Meeting in Cleveland in April.

Jason Clifford Yates, formerly Asst. Materials Engineer, National Bureau of Standards, Washington, D. C., is now Materials Engineer, Alpha Portland Cement Co., Easton, Pa.

Henry Philleo has been named Research Associate, Dept. of Chemical Engineering, North Carolina State College, Raleigh, N. C. He was previously X-ray Technician with Jack & Heintz, Inc., Cleveland, Ohio.

James Smuck, formerly with Langmuir Paints, Oakville, Ont., Canada, is now associated with Donald Inspection, Ltd., Toronto, in the capacity of Chemist and Metallurgist.

Paul M. Haenni has been appointed Director, Centre d'Etudes Industrielles, Geneva, Switzerland. He was formerly associated with the Aluminium Ltd. Training School of Geneva.

Renaldo Stefanell, formerly Electrical Technical Designer with the American Institute of Electrical Engineers, New York City, is now associated with Avianca, Barranquilla, Colombia.

A. Frank Tesi is now Asst. to the Director of Merchandising, W. T. Grant Co., New York City. He was previously Staff Engr., American Standards Assn., New York.

William M. Lehmkuhl, formerly Plant Manager, The Flintkote Co., is now Asst. Vice-President, Masonite Corp., Chicago, Ill.

Lyman Billings, formerly Process Products Engineer, Socony Vacuum Oil Co., Cambridge, Mass., is now Production Mgr., Industrial Oil & Chemical Co., Milford, Mass.

George J. Wyrough is now Technical Salesman, R. E. Carroll, Inc., Trenton, N. J. He was previously Technical Representative, Phillips Petroleum Co., of the same city.

Gilbert A. Pitman, formerly affiliated with Container Laboratories, Inc., San Francisco, is now Chemist with The Kieckhefer Container Co., Alameda, Calif.

James A. Harding has been named Project Engineer, Schlage Lock Co., San Francisco. He was formerly associated with the Marchant Calculating Machine Co., Oakland, Calif.

Helen D. Hoover has joined the staff of the International Harvester Mfg. Research Laboratory, Chicago, Ill. She was formerly with the Ahlberg Bearing Co. of Chicago.

Daniel L. Ogden has accepted an appointment with The American Metal Co., Ltd., New York City. He was previously Assistant Manager, United States Metals Refining Co., New York.

Arthur Russman has been named Industrial Textile Specialist, New York Quartermaster Purchasing Office, Dept. of the Army, New York City. He was formerly Textile Technician with the Howard Stores Corp., Brooklyn, N. Y.

Herbert J. Baker, formerly of New Orleans, La., is now associated with Corps of Engineers, Grecian District, American Embassy, Athens, Greece.

Samuel Albert Abrahams is now Mgr. of Manufacture, The Paraffin Cos., Inc., Emeryville, Calif. He was previously Factory Mgr., Plant Rubber and Asbestos Works, San Francisco.

Harold R. King is now associated as Metallurgist with the Metal & Alloy Specialties Co., Inc., Buffalo, N. Y.

Arthur E. Cozens, formerly Chief of Engineering Laboratory Section, Army-Navy Medical Procurement Office, Carlisle Barracks, Pa., has been named Materials Engineer, U. S. Corps of Engineers, South Pacific Testing Labs., Los Angeles, Calif.

Past-President H. S. Vassar, recently retired from the Public Service Electric and Gas Co. Testing Laboratory, Maplewood, N. J., has been elected an honorary member of A.S.T.M. Committee D-9 on Electrical Insulating Materials, and Committee D-11 on Rubber and Rubber-like Materials.

John Ulvad, active member of Committee D-9 for many years as representative of Otis Elevator Co., has recently been made Works Manager.

Harry A. Schwartz, Director of Research, National Malleable and Steel Castings Co., Cleveland, Ohio, has accepted an invitation from the Institute of British Foundrymen to address that organization in London on June 9. Dr. Schwartz's lecture on "Solved and Unsolved Problems in the Metallurgy of Blackheart Malleable" will be the tenth in the Edward Williams series delivered annually by distinguished metallurgists. When Dr. Schwartz attended the 1939 conference of the organization he was awarded the E. J. Fox Medal for his contribution to the literature on malleable iron, the only time the medal has ever been awarded to anyone not a British subject. Dr. Schwartz was Secretary of A.S.T.M. Committee A-7 on Malleable-Iron Castings from 1936 to 1947, and presently represents the American Foundrymen's Association in that group. Affiliated with A.S.T.M. since 1907 he has been active in many phases of A.S.T.M. work.

A. J. Warner, formerly Supervising Engineer, Federal Telecommunication Laboratories, Newark, N. J., has been transferred to the London branch of the Laboratories. Mr. Warner had been an active participant for some years in the work of Committee D-9 on Electrical Insulating Materials, and of Committee D-20 on Plastics, having served as Secretary of the latter group since 1946, and regretfully relinquished these committee connections on his departure for his new duties in England the early part of May.

Necrology

EARL H. KENDALL, Materials Engineer, Consumers Power Co., Jackson, Mich., died suddenly April 18 from a heart attack. Although his individual membership in the Society was dated 1940, Mr. Kendall had been active in the affairs of A.S.T.M. for at least fifteen years. He had rendered capable service, particularly in Committee B-1 on Wires for Electrical Conductors, of which he was the Secretary and a member of several subcommittees. He also was a member of Committee A-5 on Corrosion of Iron and Steel, serving not only as a personal member but also as the official representative of the Edison Electric Institute. While not a member of Committee D-9 he had served on Subcommittee V of that committee and as such worked in the Section on Glass Insulators. Recently he had become a member of Committee D-7, Subcommittee VII on Wood Poles and Crossarms. Associated with the Commonwealth & Southern Corporation organization since 1920, his earlier engineering activity was in industrial and electric station design, but for fifteen years he has been concerned principally with overhead line materials. He was responsible for many novel designs and inventions and was nationally known in the pole line equipment, overhead line, wire, and timber industries. In addition to his work in A.S.T.M., he was Chairman of the E.E.I. Line Hardware Subcommittee of the T&D Committee and was an active member of A.W.P.A., the National Society of Corrosion Engineers, and the A.I.E.E. In his death A.S.T.M. loses a most active member who had contributed notably to the advancement of the Society's work in the fields in which he was an authority.

J. C. PEARSON, Director of Research, Lehigh Portland Cement Co., Allentown, Pa. (March 16, 1948). Affiliated with the Society for just thirty years, Mr. Pearson was a most valuable member of A.S.T.M., contributing notably to the Society's activities, particularly in the field of cement and concrete where he was an authority. A native of Maine, he graduated from both Bowdoin and Harvard, then served on Bowdoin's faculty for two years until in 1906 he became Magnetic Observer at the Carnegie Institution of Washington, and then in 1910 began a period of fourteen years' service with the Bureau of Standards as Associate Physicist. He had been with the Lehigh Portland Cement Co. since 1924.

His technical committee affiliations were numerous, but he was especially concerned with the work of Committees C-1 on Cement and C-9 on Concrete and Concrete Aggregates. He served on many other groups as well. He was a former Secretary of Committee C-9 and an officer of several subcommittees of both these main groups. He had been honored by election to the A.S.T.M. Board of Directors in 1933, and the American Concrete Institute recognized his work through various offices in that organization culminating with the A.C.I. Presidency in 1937. Mr. Pearson served as a member of the A.S.T.M. Committee on Papers and Publications for six years and rendered outstanding service in the Society's publication program through his continuing and intensive review of papers in his field. He was always willing to review the contributions of others and to give them the benefit of his searching analysis.

One of the most modest and unassuming of men, he achieved an outstanding reputation for technical ability as well as understanding of the work of his associates and others in his field. His death is a great loss to the Society.

JAMES H. HERRON, President, The James H. Herron Co., Cleveland, Ohio (March 29, 1948). Member since 1911. While Dr. Herron had not participated in the work of A.S.T.M. technical committees, he was greatly interested in the Society, supported its work consistently and served as a prime mover in the work of the Cleveland District Council, of which he was a former Chairman. A graduate of the University of Michigan, receiving his honorary degree of Doctor of Engineering from Case in 1943, he had had a greatly

diversified experience in various manufacturing organizations. He wrote widely and participated in the work of many national engineering and technical groups. He was a Past-President of the Cleveland Engineering Society and of The American Society of Mechanical Engineers.

FREDERICK P. HUSTON, Engineer and Metallurgist, Development & Research Div., International Nickel Co., Inc., New York died (suddenly December 29, 1947, from heart attack). Mr. Huston was a member of Committee A-1 and had served on several of its subcommittees. With the International Nickel Co. for some twenty years, he was particularly concerned with the application of nickel alloys in the railroad field.

JOSEPH G. GAGNON, Chief Metallurgist, Hudson Motor Car Co., Detroit, Mich. (February 6, 1948). Member since 1935.

A. E. BAMPFIELD, Chief Chemist, Australian Cement, Ltd., Geelong, Victoria, Australia (March 18, 1947). Member since 1945. Mr. Bampfield had spent his entire career with the Australian Cement Co., and had won the first scholarship endowed by his company at the Gordon Institute of Technology in Geelong. His death is a distinct loss to the Australian cement industry.

LEO F. MULHOLLAND, Engineer of Tests, American Locomotive Co., Schenectady, N. Y. (April 20, 1948). Member since 1922. Mr. Mulholland had been actively interested in various phases of the Society's work, particularly Committee A-1 on Steel. Employed at American Locomotive since 1907, he had been very active in numerous civic and community affairs. He was the first Chairman of the Eastern New York Chapter of the American Society for Metals.

WILLIAM B. HODGE, Vice-President and Research Director, Parks-Cramer Co., Charlotte, N. C. (May 14, 1947). Member since 1936.

J. E. BOYD, Sales Engineer, Weston & Brooker Co., Atlanta, Ga. (January 21, 1948). Member since 1937. Member of Committee C-9 on Concrete, and D-4 on Road and Paving Materials.

CARLISLE W. C. PAGE, Chief Chemist, Koppers United Co., Blast Furnace Div., Granite City, Ill. (March 20, 1948). Member since 1944.

CHARLES L. SULLIVAN, JR., President, The Thresher Paint & Varnish Co., Dayton, Ohio. (January 27, 1948.) Member since 1917.

Society Appointments

Announcement is made of the following appointments:

H. A. LEEDY, Armour Research Foundation, on Subcommittee 3 on Dimensional Standards for Magnetic Recording, of ASA Sectional Committee Z57 on Sound Recording.

E. A. ABDUN-NUR, U. S. Bureau of Reclamation, on A.S.C.E. Committee on Glossary of Terms and Definitions of Soil Mechanics.

K. B. WOODS, Purdue University, on Highway Research Board of the National Research Council, succeeding Prevost Hubbard, resigned.

J. C. PITZER, Formica Insulation Co., as liaison representative between Committee D-9 Subcommittee VIII (Insulating Papers) and the TAPPI Plastics Committee.

L. H. FRY, Locomotive Research Institute; D. E. PARSONS, National Bureau of Standards, T. S. TAYLOR, United States Testing Co.; R. L. TEMPLIN, Aluminum Company of America, as members of Committee E-1 on Methods of Testing. (Reappointment)

P. V. FARAGHER, Aluminum Company of America, and L. H. Fry, Locomotive Research Institute, as members of Committee E-8. (Reappointment)

H. A. PRAY, Battelle Memorial Institute, has been appointed as a member-at-large of the Advisory Committee on Corrosion, to succeed F. L. LaQue, International Nickel Co., whose term expires at the annual meeting.

Notes on Laboratory Supplies

Catalogs and Literature; Notes on New or Improved Apparatus

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses.

Catalogs and Literature:

SCIENTIFIC GLASS APPARATUS CO., INC., 49 Ackerman St., Bloomfield, N. J. A new eight-page booklet entitled "What's New for the Laboratory" describes and illustrates various instruments such as a new cutter for glass tubing, Plexiglas test tube rack, relative humidity indicator, Adams safety-head centrifuge, voltbox, safety mats, Todd vacuum pumps, microscope lamps, slide boxes, etc.

Also a leaflet covering Stainless Steel Vacuum Dewar Flasks. Lists their features, and gives description of flasks.

BURRELL TECHNICAL SUPPLY CO., 1942 Fifth Ave., Pittsburgh 19, Pa. Bulletin No. 208 on "Metallographic Polishing Supplies" features the new metallographic polishing compound "C-RO." This compound quickly prepares the most difficult-to-polish materials often in as little time as three minutes. Burrell Polishing Cloths and Abrasives and Specimen Preparation Equipment are also described.

GENERAL RADIO CO., 275 Massachusetts Ave., Cambridge 39, Mass. Catalog L, 227 pages, profusely illustrated. This is the first completely new general catalog published in several years by General Radio Co. It supersedes all other catalogs and describes their complete current line of instruments, parts, and accessories. Sections cover industrial instruments, resistors, capacitors, inductors, bridges and accessories, amplifiers and power supplies, oscillators and standard-signal generators, waveform-measuring instruments, meters, frequency-measuring equipment, parts and accessories, reactance charts, and decibel tables. Two indexes are included, one by Type Number and the other by Title. There is also a short section in the front on "How to Order." Page size, $6^1/_2$ by 10 in.

EASTMAN KODAK CO., Rochester 4, N. Y. A new four-page catalog describing Kodak Linagraph Films and Papers for use in instrument recording has just been issued by the Industrial Photographic Division. The booklet describes 11 films and papers used to record oscillograph traces and similar phenomena. Complete information is given regarding speed, contrast, color sensitivity and other characteristics determined by the requirements of a particular instrument.

Also, a new twelve-page booklet, "Magnifying Time," describes the use of the Kodak High Speed Camera to analyze motion too fast for study by the unaided eye. Illustrated with enlargements from motion pictures taken at 1000 to 3000 frames per second, the booklet provides examples of actual engineering and industrial problems solved by ultra-speed photography. Information is given concerning the operating characteristics of the camera and of accessories commonly used.

Instrument Notes:

SARGENT HYDROASPIRATOR—E. H. Sargent & Co., 155–165 E. Superior St., Chicago 11, Ill. Capable of the maximum degree of evacuation and rated as a fast and most efficient filter pump, the Hydroaspirator has a positive seal valve system which prevents the entry of water into the suction line when suction is stopped. The excellent performance of this pump is due to the extremely precise machining which goes into its production. It is made entirely of nickel plated brass with ball valve in the side arm $\frac{3}{8}$-in. I.P.S. male thread at the top and hexagonal wrench seat. Length 4 in.

SARGENT ELECTRIC DRYING OVEN—E. H. SARGENT & Co. This was designed to fill the need of chemists for a dependable, low-cost, automatically controlled oven with a long service life. The multiple chromel wire heating elements are arranged to give even heat distribution throughout the entire oven. Ventilating system provides rapid transfer of air through the oven, which results in an exceptionally fast drying rate; the metal walls are lined with $\frac{1}{4}$ in. Transite to prevent excessive heat loss and the bimetallic thermostat main-

tains the heat in the oven to within ±1 C. of the desired temperature. The operating range is from slightly above room temperature to 200 C. (392 F.). All controls—the three-heat switch, the thermostat control, and the pilot light—are located on the front panel which is acutally the front of a drawer on which the heating elements are mounted. By removing two screws at each end of the panel the entire heating and control systems can be removed from the oven as a single unit. Maximum power consumption 850 watts. Dimensions: Outside, 16 in. by 11¾ in. by 11⅞ in. Inside 9 in. by 11¼ in. by 11¼ in.

Acculute—E. H. Sargent & Co. This concentrate is for rapid preparation of standard volumetric solutions. Transfer the contents of the Acculute ampoule to a volumetric flask and dilute to 1000 ml. with distilled water—a standard volumetric solution is prepared. There is no need for subsequent standardization.

Accutint—E. H. Sargent & Co, Accutint test papers are used for rapid. accurate, convenient pH determination. They are economical and simple to use. By using the complete set of 23 papers, 144 pH values are determinable with an accuracy of about 0.1 pH. This is possible because of the overlap in the fractional papers. Accutint covers the entire pH range from 0 to 14 and is composed of two different types of papers: Wide Range Papers, which are recommended for initial determinations or when the pH is not known to be within the limits of a fractional range, and Fractional Range Papers which will give an accuracy to within 0.3 pH.

Ash-Free Dry-Dispersed Analytical Filter Pulp, S&S No. 289—Carl Schleicher & Schuell Co., 116–118 West 14th St., New York 11, N. Y. Analytical Filter Pulp, as an aid in filtrations in quantitative analyses, was first produced by the S&S concern in Europe during 1913. Suitable for the most exacting requirements of gravimetric analysis. Recent work in partition chromatography suggests a completely new use for such dry-dispersed, ash-free, filterpulp, as adsorbent in the adsorption columns, and its application permits the separation of similar compounds of biological origin (amino acids, pigments, etc.).

Deoxo Hydrogen Purifier—Fisher Scientific Co., 717 Forbes St., Pittsburgh 30, Pa. This Purifier is a metal cylinder containing a platinum catalyst and incorporating fittings for attaching to the reducing valves on a hydrogen cylinder. It is a simple, effective device for removing traces of oxygen by catalytic action from cylinders of compressed hydrogen. It operates efficiently at a gas flow up to 5 cu. ft. per hr. and at a pressure as high as 50 psi. The catalytic action takes place at room temperature.

Jumbo Electric Stirrer—Fisher Scientific Co. Provides strong torque, is sparkproof, and its large impeller can be adjusted for vigorous or general stirring of liquids in large laboratory vessels. This Stirrer incorporates a heavy-duty, constant-torque, six-pole induction type motor for driving either a 16-in. or 18-in. stainless steel shaft with 2½ and 3½-in. propellers, respectively. It is particularly designed for mixing tars, petroleum products, plastics, paint, and varnishes.

Measure-Scope—American Instrument Co., Inc., Silver Spring, Md. This new instrument measures angles to within one second of arc, and lengths to two-millionths of an inch, with an accuracy of 0.1 per cent of full scale. Typical measurements that may be made with this instrument are as follows: dimension measurements from zero to any gage block combination; parallelism of two or more surfaces of transparent or opaque materials; angle of rotation of any surface or plane mirror, within one second of arc; comparison of angles with angle gage blocks, or with sine bar; external or internal right angles within two seconds of arc; flatness or straightness of large plane surfaces within one microinch; direction of a hole in a specimen relative to a plane; etc.

Quick Change Alloy Scales for Quantometer—Applied Research Laboratories, 4336 San Fernando Road, Glendale, Calif. This is a new recording system which is being applied to the direct-reading instrument for spectrochemical analysis—the Quantometer—to extend its range of application. The system, which employs removable plastic panels fitted with direct-reading scales for each element being determined, allows panels to be made up for each type of alloy. With this arrangement the instrument can be set up for the analysis of an alloy of a certain base metal in a few minutes.

Manometer—The Emil Greiner Co., 161 Sixth Ave., New York, N. Y. Simplicity and high precision in making either absolute or differential measurements of pressure and vacuum are obtainable through this instrument. It reduces the task of cleaning and filling a closed end manometer to the same relatively simple process of cleaning and filling an open end U-tube type. Only a single reading is required to obtain a precise measurement automatically corrected for ambient temperature and reduced to a height of mercury at 0 C.

Amsler Horizontal Tensile Testing Machine—Adolph I. Buehler, 228 N. LaSalle St., Chicago 1, Ill. This machine is designed for testing materials of small section of low tensile strength such as fabrics, papers, yarn, leather and fine wires. It is suitable particularly for testing specimens having a great elongation, such as rubber. Universally applicable, the machine includes all the features desirable in a small testing machine, such as a pendulum load weighing system, five load ranges permitting widest application, easy access and unobstructed view of the specimen, convenient gripping mechanism, and a visible indicator and automatic load-extension diagram recorder.

Precision Interchemical Rotational Viscometer—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill. This is a high-speed, wide range instrument, which measures, in accordance with the principles of modern scientific rheology, the flow properties of paints, printing inks, plastics, adhesives, food products, and similar industrial products. This viscometer produces consistency curves in place of single point measurements which are usually misleading for plastic, thixotropic materials. It consists essentially of a rotating cup containing the sample to be measured, and a stationary bob immersed in it. When the cup is rotated at the predetermined speeds, a viscous drag is imposed on a coiled spring supporting the bob, which is twisted through an angle measured on a calibrated disk. The speed of rotation of the cup may be varied from 10 to 400 rpm. in steps of 10 rpm. by using a General Electric Thy-Mo-Trol drive.

Multi-Clutch Connector—Fisher Scientific Co. This new unit provides a simple means for mounting laboratory apparatus on a support frame so that the apparatus can be moved vertically or horizontally during the course of a procedure. It attaches to two adjacent ½-in.

rods so that the connector will slide along the two rods and can be secured at any point by means of a thumbscrew. Openings are provided in the connector so that clamps, upper rods, or supports can be held by the connector. Typical uses are to support heaters, cooling traps, flasks, test panels, etc., at any desired height or transverse position on a support. It is designed particularly for use with Flexaframe Supports and Castaloy Clamps.

FISHER-STERN ULTRACENTRIFUGE—Fisher Scientific Co. By means of this instrument very large amounts of centrifugal force can be applied to samples held in a whirling rotor. The instrument develops speeds up to 20,000 revolutions per minute at an air pressure of 80 psi. and at top speed produces a force 26,000 times that of gravity. It incorporates a Lucite rotor with notched edges that are spun by air pressure.

HUNTER PHOTOELECTRIC COLORIMETER AND COLOR-DIFFERENCE METER—Henry A. Gardner Laboratory, Inc., 4723 Elm St., Bethesda, Md. This is a new instrument for direct measurements of color and small color differences in fabrics, paints, plastics, ceramics, etc. The apparatus is able to detect small differences directly and should prove suited to the needs of industry for apparatus to maintain quantitative color tolerances.

AUTOMATIC CONTINUOUS RECORDERS FOR GLOSS, REFLECTANCE, ETC.—Henry A. Gardner Laboratory, Inc. These recorders are used to obtain continuous records during a production from paper, fabrics, plastics, films, and other materials produced by continuous processes. A 75-deg. gloss exposure head has been combined with a specially modified recorder of the type widely used in industry to make a continuous gloss recorder of high precision and accuracy.

INTERCHEMICAL WET FILM THICKNESS GAGE—Henry A. Gardner Laboratory, Inc. A new instrument for measuring the wet film thickness of paint, varnish, lacquers and related products, is now available in the following ranges: 0 to 2 mils for use on very thin coatings; 0 to 4 mil gage; 2 to 12 mil gage; and 10 to 30 mil gage.

News of Instrument Companies and Personnel

Announcement has been received from B. F. PERKINS & SON, INC., paper and textile finishing machine manufacturers and producers of the Mullen Tester, that John Lewis Perkins III has been appointed Vice-President and General Sales Manager. The business was founded by his great grandfather in 1873 and this is the Diamond Jubilee year.

PRECISION SCIENTIFIC Co., Chicago, Ill., has announced the appointment of Dr. M. S. Agruss as Director of the Research and Development Department. Previous to his appointment, Dr. Agruss was a consultant in the field of petroleum technology and chemistry, and was also Research Supervisor with the Pure Oil Co. for ten years. During the war years, he was a member of the Petroleum Industry War Council, as well as associated with the Manhattan Project.

The Hanlon Award, highest award in the natural gasoline industry, was conferred March 25 on Colonel George A. Burrell, President of BURRELL TECHNICAL SUPPLY Co., Pittsburgh, Pa. The ceremony took place at the 27th annual meeting of the Natural Gasoline Association of America at Fort Worth, Texas.

Melville Eastham, Chief Engineer, GENERAL RADIO Co., Cambridge, Mass., recently received the New England Award at the Annual Meeting of New England Engineers held on April 29. Mr. Eastham's career is outstanding in the field of precision electrical measurements as well as epitomizing the best in industrial management.

The firm of SAM TOUR & Co., INC., 44 Trinity Place, New York 6, N. Y., engineers, metallurgists, consultants, is expanding its laboratories and workshops to better handle the increase in the volume of its business. Two and a half floors of additional space in its building at 44 Trinity Place are being taken over by the company. When the transition is completed, seven floors of this building will be occupied completely by this organization.

An announcement has recently been made by the National Carbon Co. that the ATLAS ELECTRIC DEVICES Co., 361 W. Superior St., Chicago, Ill., has taken over the manufacture and sales of the National Weathering Unit Model X1A including repair parts, supplies and service to present users. Atlas is well known in the field as the originator of weathering and fading equipment, and for over 25 years has manufactured the Weather-Ometer, Fade-Ometer and Launder-Ometer. Atlas is now redesigning the Model X1A to incorporate the automatic cycling and other control features of the Atlas Twin-Arc Weather-Ometer but is retaining as a light source the well-known National Sunshine carbon arc. This redesigned weathering unit will be an addition to the regular Atlas line of Weather-Ometers, Fade-Ometers, and Launder-Ometers.

Safety for the Household

THE principal hazards to safety in the home, and the means for eliminating or reducing them are discussed in detail in the new, 200-page edition of *Safety for the Household*, now available from the Government Printing Office as National Bureau of Standards Circular 463. While written mainly for the average present-day household, this booklet provides information that is also of value in the construction and safe operation of schools, hotels, hospitals, stores, warehouses, and industrial plants.

Chapters on gas, building construction, refrigerants, fire prevention, heating equipment, plumbing, fire extinguishers, electrical equipment, and other special items have been prepared by qualified specialists from the various sections of the Bureau dealing with these particular subjects. There is a chapter on suggestions for building a home and discussions of hazards in the use of hand tools and machinery. In recent years new trends in home design, new household equipment, and modern toys have brought new sources of accidents. In an effort to keep pace with the hazards introduced by these developments, sections on such topics as television and miniature gasoline engines have been included.

NBS Circular 463 may be obtained only from the Superintendent of Documents, Washington 25, D. C., at a cost of 75 cents per copy.

To the A.S.T.M. Committee on Membership, 1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send information on membership to the company or individual indicated below.

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This company (or individual) is interested in the following subjects: (indicate field of activity, that is, petroleum, steel, non-ferrous, etc., etc.)

____

Signed ____________________

Date________________ Address____________________

Research—Everybody's Doing It Now

By T. A. Boyd[1]

EDITOR'S NOTE.—This paper is a somewhat modified version of the address which President Boyd presented at meetings sponsored by A.S.T.M. Districts including Philadelphia, Cleveland, Ohio Valley (Dayton), St. Louis, New England (Boston), Southern California (Los Angeles), and Northern California (San Francisco).

INDUSTRIAL research, the change-making function of modern industry, employed before the war about as many persons as the cleaning and dyeing business. In 1940 the number of workers in industrial research laboratories was given as around 75,000, which was about twice as many as were engaged in making motion pictures.

Just as in making movies, everyone cannot be a star, nor even an actor, so in a research laboratory there must be workers of many kinds. It has been said that it takes nine tailors to make a man—but naturally none of us nowadays can afford to hire nearly all the nine. Just so to do a good job of industrial research takes men of many talents, only a fraction of whom are technical men or engineers.

Thomas A. Edison was the pioneer organizer of an industrial research laboratory. When in 1870 Edison received payment for improving the stock ticker, he set up a manufacturing business in Newark, N. J. But Edison's bent was for experimentation, and he soon found that he could not manufacture a product and develop new things with the same facilities. So he turned the factory over to a superintendent, and he himself moved to Menlo Park, where he could develop new things undisturbed. But he had more ideas than he had time and hands to work out by himself. Hence he gathered around him a group of men of various talents to assist him. Thus was formed the first industrial research laboratory, and one which became very productive. So it may be said that one of Thomas A. Edison's most important inventions was the industrial research laboratory itself.

But for a long, long time afterward very few businesses followed Edison's example. As an accepted institution the industrial research laboratory is thus quite a new thing. It has come into existence almost altogether since 1900. In point of fact, most of our industrial research laboratories were not organized until after the first World War. In the years following that war there was a big upsurge in research. By the end of the 1920's there were over 1600 industrial research laboratories in the country (**1**).[2]

This is not because war advances science, for that it does not do. War really sidetracks science. Experience has shown, though, that war does stimulate the expansion of industrial research—after the war is over. And so now, following the recent World War, an upsurge in research similar to that which occurred in the 1920's after the first World War is under way. It is retarded, however, by difficulties in building and shortages of personnel. The most recent report of the National Research Council gave the number of industrial research laboratories in the country as 2500 and the number of persons employed in them as 135,000, which is nearly twice as many as before the war (**2**).

Now research is costly, of course. Anyone who has ever tried to run a laboratory has found that out. One reason for this is that research is like art, about which the poet once said that "Art is long and time is fleeting." Research is long too, for of necessity it moves slowly; and time flies away, because most research endeavors cannot be hurried very much. Research is thus costly both in time and in money. This is why Sir J. J. Thompson said once that the most useful kind of balance for a research laboratory to have is a balance at the bank.

To be sure, it is a bit of an exaggeration to say, as my title does, that *everybody* is doing research now. Even in industry, with all the increase there has been, *perhaps 90 percent of all companies still have no research laboratories*. Thus, among the millions of business enterprises in the United States, there are said to be more than 17,000 manufacturing concerns whose gross sales exceed 500,000 dollars a year (**3**); but only about 2500 of them have research laboratories. One reason for this is that so many people still do not appreciate the importance of research, nor understand its tremendous potentialities. Another important reason lies in the belief that research is too costly and too complicated for any but large organizations to undertake.

But this latter is in large part a mistaken belief; for research, when conducted with judgment and imagination, more than pays for itself. In spite of its high cost, research is, in point of fact, one of the most profitable of endeavors.

Thus The Johns-Manville Corp. has said that nearly three-fifths (56 per cent) of its current sales are in products introduced since 1928 through research (**4**). The du Pont Company, too, has said that 46 per cent of its gross sales in 1942 consisted of products which either did not exist in 1928, 14 years earlier, or were not then made in commercial quantities (**5**). Not every single research endeavor pays out, of course, but in the long run the benefits of research far exceed the cost of it. In fact, as someone has said, the biggest gamble of all is not to do any research. But that is nevertheless a gamble which many business enterprises are still taking.

It goes without saying that a small concern cannot maintain a *large* research staff. But you don't have to have a big staff to do research. Your staff may be only one man. That man should be a versatile fellow who is familiar with the business and who can do a good job of seeking out the solution of some problem of the business. The efforts of such a man can readily be supplemented nowadays by work in research institutes, in the research foundations established by universities, and even in other research laboratories in his own industry, for much cooperative research is being done today; and some of that cooperative research is being conducted through the agency of our American Society for Testing Materials. For that matter, most of the big research laboratories of the present time were small one day. They grew large only through demonstrated service to the business. Dr. C. E. K. Mees of Eastman Kodak thinks that small companies can conduct research with particular profit and advantage, because, for one thing, the research director of a small company can be an active part of management to a far greater extent than is possible in a big organization (**6**).

Now I would not have it appear at all that what is advocated here is that every organization should increase its expenditure for research. That has to be done with judgment, for it is possible of course to have more research funds than can be spent wisely. In research it is ideas, not money, that count most. All that I have meant to imply is that there are apparently many companies not yet

[1] President, American Society for Testing Materials; Research Consultant, Research Laboratories Division, General Motors Corp., Detroit, Mich.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

The accompanying view of the Whiting Research Laboratory of the Standard Oil Company of Indiana, which buildings were dedicated in April indicates the great importance of research in industry. When completed, this laboratory will house over 300 chemists, physicists, and other scientists, along with 800 technicians and assistants.

Photos courtesy of Standard Oil Company of Indiana

doing any research at all to which it could be of great benefit.

Case History in the Field of Petroleum:

The benefits of research are not by any means restricted to the particular business enterprise which pursues it. The customer and people in general benefit too, usually to a larger extent than the company doing the research. The universal usefulness of research can be illustrated best perhaps by reciting a specific case history. The one presented shows something of how large have been the effects of research in the field of petroleum and how it has benefited all of us.

When, just 30 years ago, I began research on fuels, there was fear that petroleum would shortly be exhausted. At that time our total remaining recoverable reserves of crude oil were estimated at a mere 7 billion barrels. And only about half of that amount was proved reserves in the present-day sense. That was but a very few years' supply, of course. So the outlook was surely far from bright. This case history relates to *what* has happened during the 30 years since that time—and to *why* it happened.

What has happened, every one knows. Those gloomy estimates turned out to be altogether wrong. Nearly four times 7 billion barrels of crude oil have been taken out of our oil fields since 1918. And still today our proved reserves of petroleum in the ground are three times as large as the estimated total supply back in 1918 (**7**). Thus, that estimate has already been found wrong by sevenfold. Not only that, but during the same period our proved reserves of natural gas have increased seven-fold, until now the Btu. value of our natural gas reserves is as large as that of our reserves of petroleum.

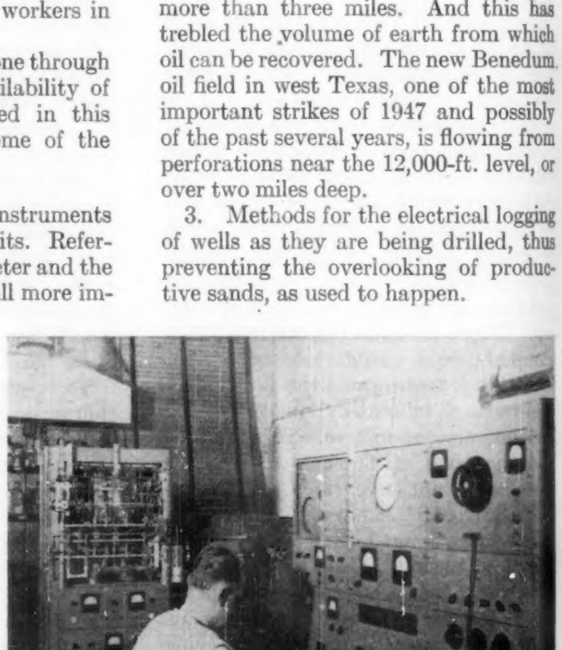
Now *why* was it that those estimates proved to be so far wrong? The answer is that it was mainly because of the results of research and the advances in technology resulting from it. When I begin research back there in 1918 there were only about 100 technical men engaged in research in the whole petroleum industry. But around 1920 that number began to grow a little. Soon the growth accelerated and it was rapid during the late 1920's. Today there are 10,000 or more research workers in petroleum.

What all these men have done through research to increase the availability of crude oil cannot be detailed in this address, of course. But some of the items were these:

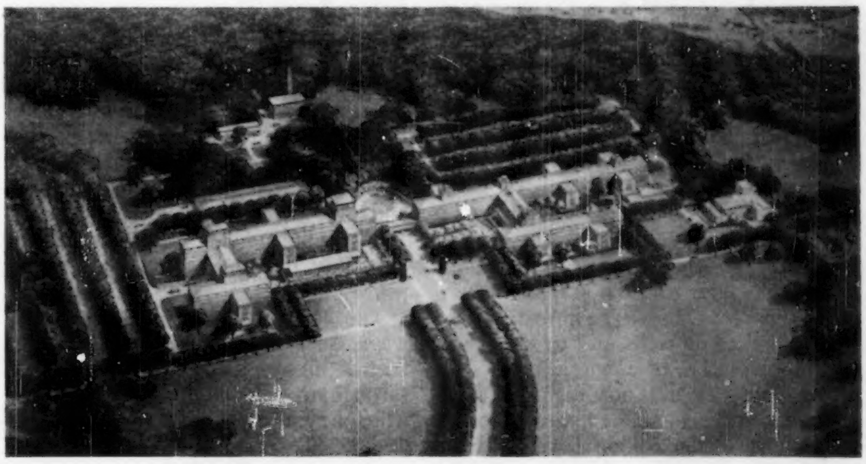
1. The use of scientific instruments for the location of oil deposits. Reference here is to the gravity meter and the magnetometer, and to the still more important seismic methods. These are scientific means of finding oil where there are no surface indications of favorable structures. An immense ammount of research and experimentation has been done in this field, and it has been highly profitable research.

2. New drilling methods, better steels, and other inventions, making it possible to sink oil wells deeper. These advances have lowered the drilling limit from 5000 ft., where it stood in 1918, to more than three miles. And this has trebled the volume of earth from which oil can be recovered. The new Benedum oil field in west Texas, one of the most important strikes of 1947 and possibly of the past several years, is flowing from perforations near the 12,000-ft. level, or over two miles deep.

3. Methods for the electrical logging of wells as they are being drilled, thus preventing the overlooking of productive sands, as used to happen.



In the Whiting Research Laboratory the mass spectrometer permits samples of hydro-carbons to be analyzed in a few hours instead of the days required before these remarkable electronic instruments were available.



Architect's sketch of the Murray Hill facilities of Bell Telephone Laboratories, research and development organization of the Bell System, situated near Summit, New Jersey. The right wing was completed just before the war and construction is now proceeding on the left wing, which is expected to be ready for occupancy late this year.

Photos courtesy of Bell Telephone Laboratories

4. Methods of gas recycling, water flooding, acid treatment, etc. These methods have made it possible to get 60 to 75 per cent of the oil out of the sands, once a field has been discovered, instead of only 20 to 30 per cent, as used to be the case.

These are some of the principal reasons why the predicted failure of our oil supply has not happened. And it has failed to happen in spite of consumption rates far, far in excess of anything dreamed of back in 1918. In the recent World War the consumption of oil was 18 times as great as it was in the first World War. And the consumption of oil has been much larger since the war closed than it was even during the war. It is so large, in fact, that a severe strain is right now being thrown on the production facilities of the industry.

Just suppose the research which yielded all these advances had not been done! Where would we have been? The answer would have to be a pretty sad one. So surely this is a case where research has been of great service to society, and to you and me as individual members of it.

But what has been told is only a part of the oil story, of course. An immense amount of highly productive and profitable research has been done, too, in the refining and utilization phases of crude oil. This research has done many things. It has made available for needed uses a larger portion of petroleum available; it has greatly improved the quality of petroleum products; and it gave us high-octane aviation gasoline, synthetic rubber, and toluene in unlimited amounts, without which products we might well have lost the recent War. But these advances, large and important though they are, will not be detailed in this case history. It may be said, however, that, in the process, petroleum refineries are becoming more and more like chemical plants, but chemical plants on a huge scale, of course.

On the utilization side, one outcome of research has been to get a great deal more work, or more ton-miles, out of each gallon of gasoline. This has been brought about by changes in cars which in turn have been made possible in large measure by considerable improvements in the octane number of the gasoline available. There are further gains to be had in this regard when gasolines still freer from knock are to be had. Thus, experiments on gasoline engines of very high compression ratios made in recent months by General Motors Research Laboratories Division have shown that a gain of at least a third in miles per gallon can be obtained by boosting still further the compression ratio of automobile engines (8). The tests showed too that the fuel required for that purpose need be no better in octane number than some which are now available experimentally. They showed, further, that a large portion of the gain in miles per gallon can be obtained with engines having compressions boosted only enough to run on gasolines which can be made commercially at the present time.

There is one other outcome of research in the field of liquid fuels that should not fail to be mentioned. In spite of the good fortune in respect to oil that we have always had, it is not reasonable to expect our oil to last indefinitely. As a matter of fact, the demand for oil products has become so huge that even now production can scarcely keep pace with consumption. But already as a result of past research we have a method of making liquid fuels and oil out of other materials—out of natural gas, out of oil shale, or out of coal. And we have vast reserves of these materials. Thus, our known reserve of natural gas is as large as that of petroleum. The reserve of oil shale amounts to five times that of petroleum and that of the coal to sixty times (9). The method by which such materials are converted into liquid fuels is by a system of hydrocarbon synthesis called originally the Fischer-Tropsch process. That process consists in converting the material first to carbon monoxide and hydrogen, in a partial combustion, and then combining those two compounds chemically under the influence of catalysts to form liquid hydrocarbons. Iron is one of the best catalysts for the purpose.

This method of making hydrocarbons by synthetic means was originally developed in Germany and used there to make gasoline and oil out of coal. But, through extensive researches conducted in this country in the past few years, the process has been greatly improved in effectiveness and reduced in cost. The degree of improvement has been so great that the process is soon to be put to use in making gasoline out of natural gas. Two plants to manufacture gasoline out of natural gas are now being built in this country. One of these being constructed at Brownsville, Tex., by an association of companies is expected to have a capacity of 7000 barrels of gasoline and Diesel oil per day. Another such plant of similar size is being constructed in southwestern Kansas by the Standard Oil Company of Indiana at a reported total cost of more than 30 million dollars. And that large expenditure by a single company gives a measure of the confidence in the practicability of the process. The gasoline made from natural gas by that process is expected to complete reasonably well in cost with that made from petroleum, of course. So, in addition to all the benefits of research on liquid fuels in the past and the present, it has given us also a measure of security for the future.

Not nearly everything has been told in this case history of research in petroleum, of course. But I am mindful of Voltaire's saying that the secret of being a bore is to tell everything. I do want to call attention to one thing more, though, for it is a point of importance in

all research. And that is the circumstance that not all the research which benefited the petroleum industry was done within the industry itself by any means! Although the industry is currently expending about 100 million dollars a year on research, it does not do all the research which helps in its advancement. The industry did not originate the gravity meter, the magnetometer, nor the seismograph. It did not do the major research in metallurgy which has contributed so mightily to the drilling of oil wells and to the successful operation of modern methods of refining. It did not dig out the original knowledge about hydrocarbons upon which higher octane gasolines are based. But the point of importance is that in all these cases it *was* alert to seize upon such knowledge when it was obtained. Also, the industry had provided itself with the research facilities needed to adapt such knowledge to its own case and to put it to work.

Second Case History—Atomic Energy:

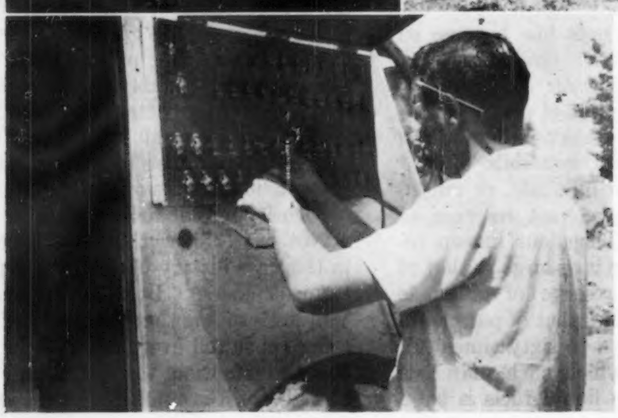
New products are not born full-grown, as the goddess Athena is said to have sprung from the aching head of her father, Zeus. They come into existence only after a long period of development or growth. A significant instance of this is atomic energy, which is of so much interest and concern to every one of us today. The atomic bomb was a wartime climax of researches conducted by men and women of many nationalities, and over a period of nearly 75 years. And this is true likewise of the present-day effort to harness atomic energy for peacetime use.

The story begins back about 1875, when Sir William Crookes discovered that if high voltage electricity is sent through an evacuated tube emanations, which he called "cathode rays," are produced. Later, Sir J. J. Thompson studying those cathode rays, found them to be particles of negative electricity, which came to be called "electrons."

In 1895 Roentgen in Germany, by bombarding metal targets in a vacuum with electrons, discovered X-rays. That discovery prompted the Frenchman, Bacquerel, to investigate substances which glow in the dark and in doing so he found that uranium gives off radiations similar to X-rays. Bacquerel's experiments started Madam Curie, a Polish girl and her French husband, Pierre Curie, on their long laborious chemical research on pitchblende, from which in 1898 they isolated radium. And that new element was observed to be in a constant state of natural or spontaneous disintegration. Radium was observed to be more than a million times as active as uranium, giving off electrons and heavier positively charged particles which were called "alpha" rays, along with a quantity of energy.

Then in 1902 Ernest Rutherford, a native of New Zealand, and Frederick Soddy, an Englishman, working at McGill University in Montreal, showed that the alpha rays from radium were really atoms of helium minus two electrons. So here was one element turning into another. But so preposterous did Rutherford's ideas seem at the time that the authorities of McGill are said to have been afraid that on account of him the university would be held up to ridicule.

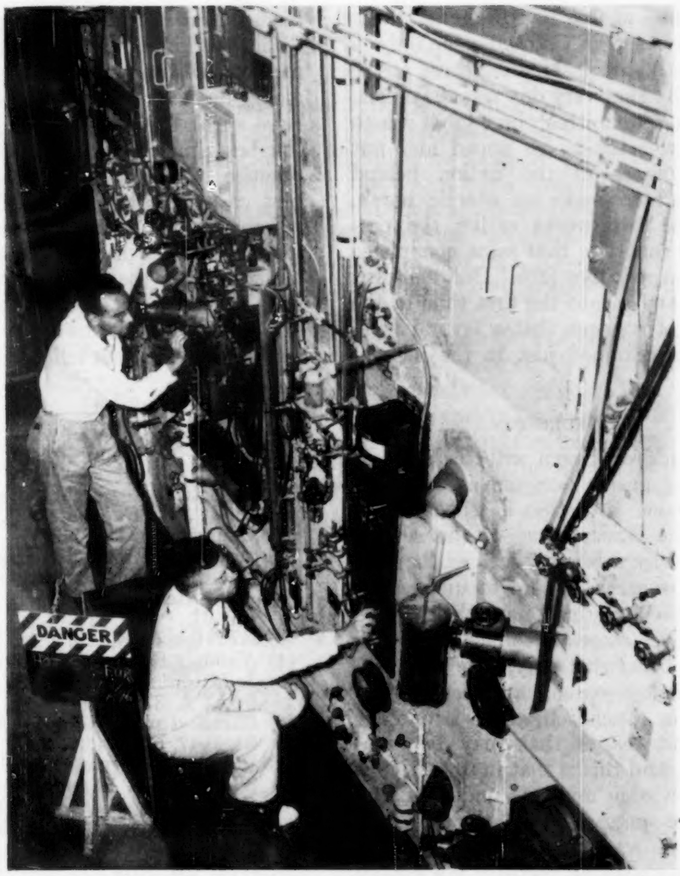
Later, in 1911, Rutherford formulated a model of the atom as a positively charged nucleus with electrons spaced around the heavy nucleus about as we know it today. In 1913 the Danish scientist, Niels Bohr, extended and per-



Modern Oil Prospecting
Geophysical Crews Working in Louisiana

Upper Left: Drilling crew preparing to run casing; Center: Packing dynamite in hole; Upper Right: Shot blowing casing out of hole; Lower Left: Observer connecting leads in recording truck

Photos courtesy of Atlantic Refining Co.



Two operating chemists at controls and periscopes view chemical process for separating the dangerously radioactive fission products of uranium. The operators are protected by thick concrete and lead.

fected ideas that had gone before him. He conceived the atom as containing an equal number of positively charged protons and negative electrons held together by mutual attraction and arranged as a dynamic system with the protons in a central nucleus and the electrons as a surrounding planetary system. That matter does have some such definite pattern of structure was soon verified experimentally by the Englishmen, Sir William Bragg and his son W. L. Bragg, and by H. G. J. Moseley. The latter was the brilliant young British scientist who, by having been killed in World War I fighting at Gallipoli, became the representative example of what not to do in wartime with men trained in science.

Rutherford believed that, if the nucleus of an atom could be fractured, different kinds of atoms would be produced. In 1919 by means of alpha particles from radium he succeeded in knocking protons out of the nucleus of nitrogen, but he did not have a projective powerful enough to split the atom. There is a story that a delegation of British scientists visited Rutherford during the first World War—he was by then Sir Ernest Rutherford, head of the Cavendish Laboratory at Cambridge University—to get him interested in working on submarine devices. But he refused to quit his atomic experiments on the ground that splitting the atom was more important than the war. An effective means for splitting the atom was at last provided in 1931 when Dr. E. O. Lawrence of the University of California invented the cyclotron.

In 1932 the Frenchman, M. Joliot, and his wife, Irene Curie Joliot, bombarded atoms of beryllium with particles from radioactive polonium. In that experiment they observed a strange effect. Their experiment was repeated later in England by Sir James Chadwick, who observed that the strange effect was due to a particle which has the mass of a hydrogen nucleus but carried no electric charge. The particle which was distined to play a very important part in respect to atomic energy, was given the name "neutron." Soon the Italian physicist, Enrico Fermi, was bombarding different kinds of atoms, including uranium, with neutrons. This is the same Fermi who later directed the construction of that experimental uranium pile at the University of Chicago which on December 2, 1942, accomplished for the first time the initiation, control, and stopping of the chain reaction releasing atomic energy (**10**).

In 1935 Prof. Arthur Dempster of the University of Chicago, using a mass spectrometer, detected the presence of the important isomer of uranium with atomic weight 235, three less than the 238 of the ordinary uranium atom. And in January, 1939, Hahn and Strassman, two German scientists, published a paper showing that barium was produced by bombarding uranium with neutrons. Hahn, the senior member of that German team, had studied with Rutherford at McGill in 1905.

Dr. Lise Meitner, a famous Austrian woman physicist, who was then at the Kaiser Wilhelm Institute in Berlin, speculated on the results of Hahn and Strassman and surmised that they must have split the uranium atom and got krypton also. As krypton is an inert gas, it could easily escape detection. And if uranium had been converted into barium and krypton she knew from the sum of the atomic weights of the two elements, that some mass must have disappeared or been converted into energy. At this point Dr. Meitner, who was strongly anti-Nazi, got out of Hitler's Germany by a ruse, saying that she was going to Holland for a vacation. The Gestapo stopped her at the border; but, not knowing just who the little old gray-haired woman was, they let her go through.

Soon Dr. Meitner showed up in Copenhagen at the laboratory of Neils Bohr. There with the help of a nephew, O. R. Frisch, also a refugee from Germany, she bombarded uranium with neutrons and got barium and krypton along with the release of atomic energy, just as she had surmised.

Meitner and Frisch then sent a cablegram to Neils Bohr, who at the time was attending a conference on theoretical physics in Washington, D. C., saying that they thought they had split the uranium atom and asking that others check their observation. The cablegram was read before the meeting in Washington. And so great was the interest in atomic physics by that time that, before the meeting was over, four laboratories—Columbia University, the University of California, Johns Hopkins, and the Carnegie Institution—had reported positive experimental confirmation of the results of Meitner and Frisch.

Then the race started. The process of splitting the uranium atom thus demonstrated was termed "fission," and during the year 1939 nearly 100 papers on the subject were published. So from here on the story gets too complicated to relate. But everyone is pretty familiar with it, and with the many other problems that had to be solved and the huge

expenditure of human effort that had to be made before the spontaneous release of atomic energy became reality in the atomic bomb. The total effort amounted at least to a million man years.

The purpose of this account has been to show how long and torturous was the path which led up to the stage of knowledge at which actual development work could be begun. And, although the story is long, it has not included everything by any means. Nothing, for instance, has been said about the sucessful separation of isotopes by Aston in England 25 years ago using the principle of the mass spectrograph and by Urey at Columbia University later using a diffusion method, processes by which the needed uranium-235 was later separated from the unwanted uranium-238. But the story does show, I hope, that the present-day effort to harness atomic energy for peacetime use is possible only because of long years of prior research and experimentation on the part of many, many persons. "Perhaps never," said Arthur H. Compton, "was the making of an important invention shared by so many persons in all parts of the world" (10). But this accumulative aspect of research, this building on foundations previously laid by others, is a thing which characterizes nearly every new development.

This research, like most others, had its critical periods too. Thus, Dr. Compton has told also the story of how the success of that first uranium pile at the University of Chicago came only in the nick of time. Meeting there at the university that very day was the official reviewing committee whose job it was to decide whether to go ahead and put the resources of the nation behind the effort to make an atomic bomb. And just two weeks earlier the provisional report of that same committee had been negative (10). But that was not by any means the first time in the history of research that a favorable result was obtained just in the nick of time.

Conclusion

This address began with the implication that nearly everyone is doing research now. But that is still far from being the case. Some of the several reasons why this is so, such as the high cost of research, failure to understand that in the long run it nevertheless pays for itself, shortage of qualified personnel, and the belief that only large organizations can do research, have been cited.

But, in conclusion, there is another important reason that may be mentioned. And this is that in some things our knowledge and our understanding have not progressed to the point at which we even know just what researches would be useful. We simply have not got that far yet in the slow evolution of our knowledge. It is a little like the following story. A professor of medicine at a university out in California was giving his final lecture to the members of one year's class. "Gentlemen," he said, "during the months we have spent together I have given you the best information available on the practice of medicine. I have used the best case histories I could find. But before we part I want to caution you that the science of medicine is developing so rapidly that in a few years perhaps half of what I have taught you will prove not to be so. And, unfortunately, I cannot tell you which half it is."

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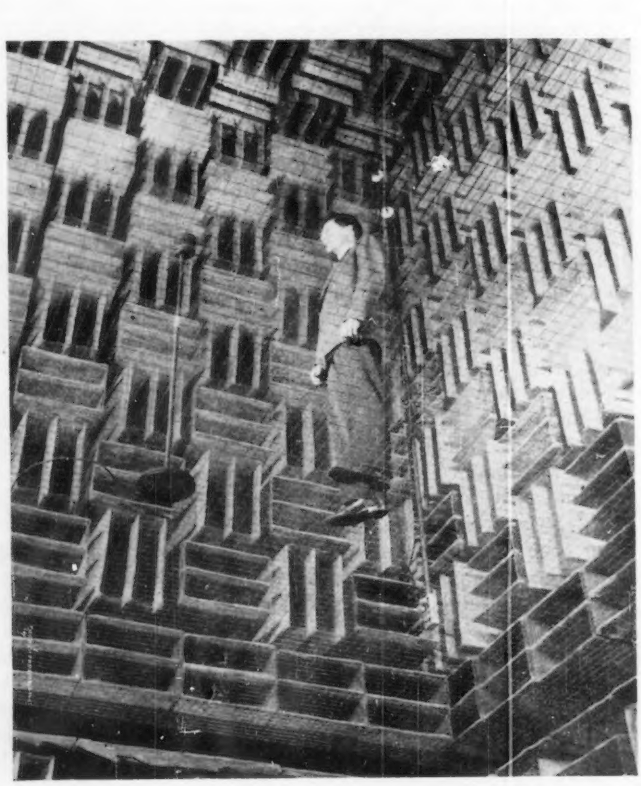

One of the quietest places on earth. This sound-proof room, recently constructed at Bell Telephone Laboratories, Murray Hill, N. J., is so designed that even a heartbeat may break the silence. Walls, ceiling and sub-floor are lined with wedges of fiberglass five feet deep. The working floor is of high-strength steel cables, strung under tension, and will support tons of equipment.

Symposium on Service Experience with Inhibited Turbine Oils

The Symposium on Service Experience with Inhibited Turbine Oils was held on February 9, 1948, at a meeting of Technical Committee C on Turbine Oils of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants in Washington, D. C. The purpose of the Symposium was to give A.S.T.M. personnel a better understanding of turbine construction and results of lubrication of central station and industrial turbines with inhibited oils.

Inhibited oils have been used since the early thirties for turbine lubrication, but they came into their own during the war years. To date practically all operators of industrial turbines and most of the operators of central stations are using inhibited oils.

Included in the Symposium are the following papers:

An Evaluation of Inhibited Turbine Oils *Versus* Uninhibited Turbine Oils for Turbine Lubrication—M. D. Baker
Service Experience with Turbine Oils—C. L. Pope and O. V. Sprague
The Care of the Lubricant and Maintenance of the Lubricating System for Central Station Turbine Equipment—E. F. Walsh
Steam Turbines and Their Lubrication—C. D. Wilson

Frank C. Linn
Chairman, Technical Committee C

An Evaluation of Inhibited Turbine Oils Versus Uninhibited Turbine Oils for Turbine Lubrication[1]

By M. D. Baker[2]

Today the demand for power requires operation of equipment on a full-time basis and outages must be reduced to a minimum. The purpose of this paper is to evaluate turbine oils for continuity of service and the prevention of outages due to faulty lubrication.

First, let us consider the unprecedented demand for power. Studies made a few years ago estimated that a single utility having no outside connected power should have 30 per cent spinning reserve of its peak demand to insure continuity of service to all customers at all times. If a number of companies were interconnected on a power grid, a reserve of 20 per cent of the total connected peak load would be needed. At the present time the power demand of the entire United States has reduced the reserve to 10 per cent in the least pressed areas and to zero or less in the other areas. The over-all average reserve has been estimated to be between 2 per cent and 5 per cent with a large potential load waiting to be connected. The shortage is predicted to last until 1950 or 1951 when it is hoped that the installations now being made will produce sufficient power to meet the estimated demands. According to the January, 1948, issue of *Fortune* magazine, the power industry is engaged in a five to six billion dollar expansion program that is to be completed in 1951. This is the largest program ever attempted or planned by the power industry and will mean a 37 per cent increase in capacity.

When the load demand on the West Penn System is at its peak we go on what is called emergency load conditions. This means that throughout the company any operation that is not essential for the immediate production of power at the peak demand is discontinued. At Springdale Station with coal handling and similar work delayed to off-peak hours, it means that an additional 5000 to 6000 kw. are placed on the lines for the customers. The laboratory contributes its 30 to 40 kw. by delaying all but immediately essential analyses. Work that is delayed is completed on off-peak hours and on an overtime basis if necessary. The above statements emphasize that continuity of service of all equipment must be maintained as near one hundred per cent as possible.

During 1947 the base load units of the West Penn Power Co. were in service between 96.2 and 98.5 per cent of the time. These same units are not scheduled for any major outage during 1948 and are to be in service between 98 and 100 per cent of the time. Any removal from service will be caused by an emergency condition or required inspection. Power replacement costs during an outage are an important item. If the most efficient unit were out of service during peak hours, the replacement of its capacity with purchased power means an outage loss of $600 an hour. If the power does not have to be purchased but can be generated on less efficient units on the system, the outage loss is reduced to between $200 and $300 an hour. The price of the batch of oil in this unit is much less than the cost of one day's outage.

Lubrication is one of the essential factors that must be considered for the delivery of the service demanded. During the past eight or ten years considerable time has been spent in an effort to evaluate the benefits of inhibited turbine oils *versus* uninhibited oils. Information secured from the users of both types is to the effect that satisfactory service is being obtained with the product they are using and there is no need for a change to be made. Quite frequently when a change from the use of an uninhibited oil to the use of an inhibited oil is considered it is not made because failures of inhibited oils have been too generally publicized. These reported failures raise the question whether or not a product which has not been entirely satisfactory but of known characteristics should be re-

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[2] Chief Chemist, West Penn Power Co., Pittsburgh, Pa.

placed with a product of questionable merit. When failures of the uninhibited oils occur they are not usually mentioned, not with the idea of withholding information, but because these failures are considered in the light of routine occurrences. As the advocates of each school base their opinions on "satisfactory service," several years ago an unbiased survey was started to determine just what this term included. To date only one common denominator has been found. That is, very few, if any, companies have a lubrication history that is sufficiently complete to permit an intelligent and unbiased study to be made.

The following eight items and some others not listed should be considered when making a study:

1. The life and analyses of the oil.
2. Cleanliness of the system holding the oil.
3. Number of outages due to lubrication troubles and what caused the outage.
4. Number of lubrication problems corrected on outages due to other reasons.
5. Number of bearing failures on all equipment, especially if light turbine oil is used for general lubrication. Light turbine oil is frequently removed from turbine reservoirs to permit higher makeup in the units.
6. Failures due to the lubricant, foreign material in the lubricant, or fault in the equipment.
7. Frequency of cleaning and amount of material cleaned out of lubricating system.
8. Corrosion of or in oil systems.

More of this information has been available during the past year as recent demands for continuous service have emphasized to the operating supervisors many items that were previously overlooked.

Some of the questions that actually have been asked by supervising operators are:

1. Is it necessary to maintain two batches of oil for one unit so that the oil can be rested and kept in condition? Cannot one batch of oil be used continuously and avoid the unit outage needed to change batches?
2. Why is it necessary to add 20 to 30 per cent oil each year to a batch in service to sweeten the oil?
3. Does the excess oil removed from a sweetened batch give satisfactory lubrication in auxiliary equipment? Can bearing failures in auxiliaries be attributed to the wrong grade of lubricant?
4. Are bags on Bowser filters cleaned every two weeks? How can the periods between cleanings be extended?
5. Is the maintenance of one common oil reservoir for all units in a plant an economic practice? Are more outages than generally realized primarily caused by a lubrication fault?
6. Can the two week-end outages a year needed to clean oil filters and reservoirs be eliminated?
7. Can oil life of a batch be extended beyond three years?
8. Is it necessary to dismantle completely the oil system of a unit at periodic intervals to remove sludge and varnish accumulations?

No doubt many more questions are being asked, as now the reasons for any unit outage are being carefully analyzed.

The use of oxidation inhibited oils was started in one unit of the West Penn Power Co. in 1936. Since then the use of these oils has been extended to all steam-driven units in the company. The first batch of oxidation inhibited oil was placed in a 40,000-kw. unit in 1936. The reason for doing so was that this unit had a bad oil history for the previous five years. Oil in this unit would last 8000 to 10,000 service hours before a neutralization number of 0.80 was reached and a heavy sludge would form when the oil was emulsified with water. On a duplicate unit the life of the same brand of oil would be 25,000 to 30,000 hr. On each unit it was necessary to clean the filter bags and the oil coolers on the oil side at least three times during the life of a batch of oil. Quite frequently it was necessary to use a chemical solution to remove the sludge and varnishes that had accumulated on the tubes of the cooler. On both units at the annual overhaul it was necessary to dismantle completely all oil lines and steam clean them, thoroughly clean the reservoir, filters, and pedestals to remove sludge.

It is of interest to note that the short life of the oil in the one unit can be attributed to the chemical cleaning of the oil coolers. In 1931, after using caustic and alkali silicate cleaning solutions, the varnish on the cooler tubes was not removed and a bath of sodium cyanide was used. This material cleaned the tubes but it also activated the metal surface so that it would quickly poison the oil that was placed in the system, causing the oil to oxidize rapidly and form sludge. After this cleaning the accumulation of material on the cooler that was formed with uninhibited oils could be removed only by the use of a chemical solution. Each cleaning reactivated the metal surface and the breakdown cycle was started again. With the use of the oxidation inhibited oil it has never been necessary to chemically clean the cooler bundle. The bundle is cleaned on the oil side at three- to five-year intervals by placing it in a bath of mineral spirits and agitating with air. The small accumulation of sludge is easily removed, but the oil film that passivates the metal to prevent poisoning is not removed.

Within a year after the first batch of inhibited oil was placed in the first unit, a batch was placed in the second unit. Since then neither batch has been replaced, and normal makeup which is about 10 per cent per year has been sufficient to maintain inhibitor concentration and prevent oxidation. The service life on each batch is now approximately 95,000 hr. The units are inspected regularly to determine the condition of the oil systems. The oil coolers have not been cleaned on the oil side since 1944. The bags on the Bowser filters were replaced this past year, the first replacement or cleaning since 1942. Deposition on the bags was gradual, indicating that no rapid breakdown condition was developing in the oil. Oil lines are not dismantled at overhaul periods and the only cleaning of the reservoir and filter is wiping with a lintless rag. The neutralization number on these oils varies between 0.03 and 0.06, the steam emulsion between 100 and 170, and the interfacial tension is approximately 30 dynes.

These statements might create an impression that inhibited oils are expected to last indefinitely and that all worries can be dispelled. Such a condition as this would give great peace of mind if it could be attained. The units mentioned have maximum bearing discharge temperatures of 140 F. The same oil that is giving superior service at this temperature when placed in a 2500-kw. unit with bearing discharge temperatures of 165 F. does not have indefinite life. Uninhibited oils in the 2500-kw. unit have service lives varying between 3000 and 8000 hr. The inhibited oils have service lives varying between 13,000 and 35,000 service hours. The difference in service life can be explained as a function of the cleanliness of the oil system when the oil is placed in the unit and the cleanliness of the oil while it is in service. This unit is not yet equipped with an oil filter. The information obtained from this unit gives a basis for predicting the breakdown of the oil in the main units. The histories of all batches of inhibited oil in the 2500-kw. unit have been similar. They show that from the time of the

initial break in neutralization number and interfacial tension, the oil was in service approximately 2000 hr. before it started to deposit sludge. By that time the neutralization number had increased to 0.25 or 0.30, and the interfacial tension had reduced to 20 or 25 dynes.

It is understood that the inhibitor has been exhausted when an oil breaks. The change that has occurred in the oil does not permit any beneficial effect to be obtained by the addition of a concentrated charge of fresh inhibitor. Some attempts have been made to add a concentrated charge of inhibitor to an oil of this nature in an effort to prolong the life of the oil, but to date no real success has been obtained from such an effort.

The length of time from the initial indication of breakdown until the oil will form sludge is sufficient to arrange for an emergency week-end outage of a unit to replace the oil; or if load condition becomes so critical that an outage cannot be permitted, the following reclaiming procedure can be used: The oil that has started to break down will be filtered by by-passing through a clay filter which will chemically purify the oil. When this filtering has reduced the neutralization number to 0.03 or less and restored the interfacial tension to some predetermined value the concentrated inhibitor solution will then be added. Before adding this solution the clay filter will be discontinued. Filters in continuous operation on a unit should remove only sludge, foreign material, and water from the oil and not produce a chemical change in the oil. As no service record is known of an oil that has been treated as described, a careful check will be maintained to determine the effectiveness and permanency of such treatment.

So far only oxidation inhibitors have been discussed. With the advent of the oxidation inhibitors and their preventing the formation of oxidized compounds in the oil that served as natural corrosion inhibitors, corrosion in oil systems has occurred. Corrosion was first reported in new units that were initially started with an inhibited oil. At Springdale Station in 1938 a 50,000 topping unit had such severe corrosion in the oil system that the corrosion products prevented governor operation. During the time required for cleaning of the oil and the oil system, the laboratory was handed the problem of determining how future corrosion could be prevented. In a crude laboratory test it was found that the oils in some of the other units in the station would inhibit the corrosion of a steel bar in a water and oil emulsion while the oil in the topping unit would not prevent corrosion when placed on the same test. Further experiment showed that a mixture of 10 per cent old oil and 90 per cent of the oil in the unit would inhibit corrosion. This mixture was placed in the unit and all further corrosion was stopped. Corrosion had originally occurred in the presence of 0.1 per cent or less of water by volume. After the mixture was placed in the unit, water was present in the oil most of the time. During the last three weeks of operation before the unit was dismantled for repairs, the oil contained 3 per cent water and 50 gal. per hour of water were removed from the oil by a centrifuge. The oil in the unit during this period would not pass the corrosion test but no further corrosion occurred in the unit.

This initial work at Springdale was praised by some users and refiners and severely condemned and ridiculed by others. The praise came from those who benefited, the condemnation from a few oil refiners and those who tried the addition of old oil without benefiting. All used oil will not inhibit corrosion and oils should be tested and found satisfactory before using them for corrosion inhibition. The severe critics were the oil refiners who claimed that additions of used oils to new oils were ruining their products. Oil research laboratories started on a program that has not been completed but which has produced many beneficial results. Some corrosion inhibited oils now obtainable are satisfactory in service. Some refiners have completely reversed their opinions regarding the use of corrosion inhibitors. That is, they are loading the oils with a corrosion inhibitor that has raised the neutralization number to 0.15 or higher and the steam emulsion number in excess of 350 sec.—values higher than ever obtained by West Penn by the addition of old oils to new oils. They also admit that the addition of the corrosion inhibitor has shortened the life of their new oil. It is possible to buy oils that satisfactorily inhibit corrosion with a neutralization number of 0.05 and steam emulsion of 100 sec. or less that have as long a test life on the oxidation test as the oxidation inhibited oil without the corrosion inhibitor. It seems rather paradoxical that the utilities should now be asked to accept as a lubricant an oil that is also used as a paint vehicle or a plating solution when previously they were so severely condemned for trying to keep their equipment in service by the addition of old oil. It may be that the cooperative work of Wm. P. Kuebler of Westinghouse and of the oil companies was stopped too soon.

Another trouble with oxidation inhibited oils has been the use of this oil in a faulty aligned bearing or a bearing with too small a surface for the load it carried and failure resulted. The rate of oxidation of the inhibited oil was so slow that natural oxidation compounds having a lubricant effect did not have time to form. The result was a bearing failure, not due to the lubricant, but due to a design fault that had previously been compensated for by oxidized oil. Most, if not all, corrosion inhibitors produce partially the effect of an extreme pressure lubricant, and oils so treated are initially better lubricants than the old uninhibited oils.

Summary

Oxidation inhibited oils have given satisfactory service for steam turbine lubrication in the West Penn Power Co. since 1936, oxidation and corrosion inhibited oils since 1943. All steam-driven prime movers on the system are lubricated with these oils. Service life of the oxidation inhibited oils has been at least three times the life of uninhibited oils under severe conditions. Under normal conditions the life has not been determined. Oil coolers are cleaner and need very infrequent cleanings. When cleaning is needed, it can be done without resorting to chemical cleaners. Filter bags have approximately five years' service between cleanings. During overhaul periods no radical cleaning is needed for the oil system. Corrosion has been eliminated. Experience based on oils that have had to be replaced in the more severe service units gives information that will serve as a guide to predict the end of the service life of the oil in other units.

Service Experience with Turbine Oils[1]

By C. L. Pope[2] and O. V. Sprague[2]

THIS paper is written for the purpose of furnishing some operating experience on lubrication systems of steam turbine generating equipment at Kodak Park. It is recognized that many factors influence the oil systems of turbines so that experience from plant to plant will vary until a common denominator can be found.

Description

Kodak Park generates its power with relatively small units. They range from 1500 kw. to 5000 kw. with steam at 260 psi. having a total temperature at the throttle of 576 F. to 800 psi. pressure having a total temperature of 750 F. All turbines operate with a centrifuge continuously by-passing the oil. Weekly inspection of the centrifuge is made. Monthly oil samples are taken, analyzed, and recorded. Yearly oil samples are taken, run in the EK-Oxidation-Corrosion Tester[3]. Each year the main oil tank is drained and inspected, the governor mechanism examined, the oil cooler water pressure tested, and the bearing covers lifted. Every three years an internal inspection is made and the oil cooler cleaned if necessary. Oils in service are broadly classified as type A (a nonsolvent refined, nonadditive oil), type B (a solvent refined, nonadditive oil), and type C (a solvent refined oxidation inhibited oil). Type D, (a solvent refined oil with both antioxidant and antirusting additives), has not been in service a sufficient length of time to allow comment. The following oil system temperature data may be considered typical.

Oil to the cooler	137 F.
Oil from the cooler	116 F.
Oil from No. 1 Bearing	148 F.
Oil from No. 2 Bearing	134 F.
Oil from No. 3 Bearing	128 F.
Oil from No. 4 Bearing	118 F.
Water to the cooler	Lowest, 34 F.; Highest, 75 F.

Some machines are three bearing machines and there is little difference in temperature between a 3 and a 4 bearing machine. The centrifuges by-pass 7 per cent to 10 per cent of the oil in the system per hour. Oil temperatures are recorded hourly on all machines in the turbine room log together with the amount of oil added to the systems and any other observations.

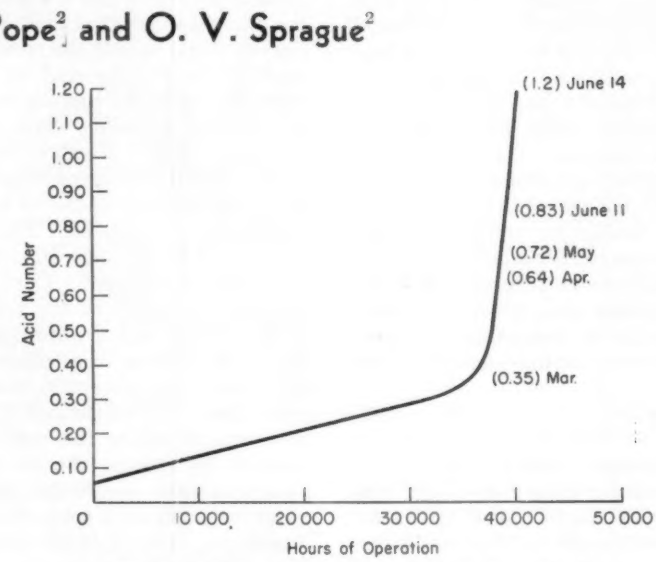

Fig. 1.—Oil Analysis No. 10 Turbine, Type B Oil.

Oil Test Interpretation

From 1930 to 1938 we attempted to judge the condition of the oil by means of monthly oil tests for water and sediment, viscosity and acid number. Occasionally oil samples were sent to the oil companies for comments. We were disappointed that we were not able to forecast the service life remaining in the oils from these records. Frequent and extensive inspections were necessary in order to provide continuity of service. The reason ascribed to this has been the nature of the physical changes in type B oil as it oxidizes. Figure 1 shows a typical oil analysis with resultant varnishing and sludging during this period. The acid number was the most significant physical change but by the time it changed sludging had commenced. The correlation between the rapid rise in acid number and the sludging was obtained by noting the increase in water to the cooler in order to maintain safe operating oil temperatures. In some cases of varnishing and rusting, the governor pistons had to be driven out with wooden blocks and the overspeed trip mechanism was entirely inoperative. We are fortunate that we enjoy very competent, alert turbine operators together with good records so that no serious trouble developed.

From 1938 to 1944, interfacial tension between oil and water was taken on the monthly oil samples together with the above-described tests. This test appeared to be valid and disclosed a change in the oil long before any significant change in color, viscosity, or acid number was noted. Table I shows typical analysis of used oil, types A, B, and C during this period. A practice of changing oil when the interfacial tension dropped below eighteen was followed during this period with a complete absence of sludging or varnishing.

TABLE I.—OIL ANALYSIS.

Hours	Oil Type	Viscosity, 100 F.	Acid No.	Interfacial Tension	H_2O and Sediment
New oil	A	314	0.05	39.0	None
	B	150	0.03	35.2	None
	C	153	0.03	38.5	None
5 000	A	314	0.07	28.3	Trace
	B	151	0.08	25.4	None
	C	154	0.02	38.0	Trace
10 000	A	315	0.12	21.7	Trace
	B	150	0.14	26.3	None
	C	157	0.02	40.3	None
15 000	A	312	0.10	22.2	Trace
	B	149	0.17	24.2	None
	C	161	0.02	36.6	Trace
20 000	A[a]	308	0.14	21.1	None
	B	148	0.21	20.0	None
	C	155	0.02	38.0	None
52 000+	C	160	0.05	27.0	None
38 000	B	149	0.35	16.2	None
39 200	B[a]	148	1.2	11.3	None

[a] Oil change.

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[1] Presented at the Symposium on Service Experience with Inhibited Turbine Oils at a meeting of A.S.T.M. Technical Committee C on Turbine Oils of Committee D-2 on Petroleum Products and Lubricants held in Washington, D. C., February 9, 1948.

[2] Lubrication Engineer and Asst. Supt. Power Plant, respectively, Eastman Kodak Co., Kodak Park, Rochester, N. Y.

[3] C. L. Pope and D. A. Hall, "Oxidation-Corrosion of Lubricating Oils," ASTM BULLETIN No. 121, March, 1943, p. 25.

About 1944 changes occurred in turbine oils. Some had antirust additives so that the initial interfacial tension was below our operating criteria. Others, instead of having a flat induction period with a rather gradual drop in interfacial tension, showed varnishing and sludging the EK-Oxidation-Corrosion Test with a rather high interfacial tension. This made it necessary to run an accelerated test in the laboratory to plot the breakdown of the oil and, furthermore, to take yearly oil samples from the system and run them in the laboratory to break down. If the initial oil ran, say, 650 hr. in our accelerated test and the used oil, after 25,000 hr., ran 325 hr., we could estimate that half of the useful life had been obtained and an oil change could be predicted at about 50,000 hr. Our makeup oil of roughly 10 per cent per year of the total oil in any system seems to provide sufficient additive to stabilize the oil with a laboratory test life somewhat shorter than a new oil. Figure 2 shows the data upon which the above statement is based. No difficulty has been experienced with sludging or varnish to date.

Rusting

Rusting of oil drain lines has occurred with both types B and C, neither of which passes the A.S.T.M. rusting test D 665–46 T.[4] No rust has been observed in the main oil tanks and bearing pedestals either above or below the oil level. Vibration of No. 11 Turbine loosened rust in a bearing drain line and wiped No. 1 bearing on January 5, 1948. It is hoped that type D oil will correct this source of rust in the only place that we are having trouble at the present time in an oil system. No rusting has been observed with type A oil which does pass the A.S.T.M. rusting test. This type of oil, as is to be expected, gives a relatively short service life of about 20,000 hr. in turbines with 550 F. steam and we usually find a small amount of soft sludge. Rust removal from oil pipes is difficult and we are never sure that we have it all out. Copper high-pressure oil pipes inside of steel low-pressure pipes preclude the use of inhibited acid for cleaning. The welded construction with many sharp bends is not conducive to turbining. Circulation of caustic solutions and blowing with steam does not completely clean the pipes. Unless we can prevent the initial formation of rust or design our piping so that it can be dismantled, we are faced with a hazard from rust formation. It is believed that flanged connections to provide relatively straight lengths of piping are worthy of consideration although none of us like any more connections then absolutely necessary. A similar problem to the rusting of oil pipes is the mill scale that we find in them and the burrs from drilling holes to weld in thermometer wells, etc.

[4] Tentative Method of Test for Rust-Preventing Characteristics of Steam-Turbine Oil in the Presence of Water (D 665 - 46 T), 1946 Book of A.S.T.M. Standards, Part III-A, p. 940.

TABLE II—TURBINE AND OIL STRENGTH DATA

	Turbine No. 12	Turbine No. 11	Turbine No. 10	Turbines Nos. 1, 2, and 6
Date installed	1941	1937	1935	1930, 1935, 1930
Steam pressure, psi	800	800	260	260
Steam temperature, deg. Fahr	750	750	575	575
Extraction h. p.	260	None	None	None
Extraction l. p.	135	None	None	None
Exhaust	3/5	135	70	3/5
Rpm	3600	3600	3600	3600/570
Oil capacity	750	550	212	610
Gal. of oil used per 1000 hr.	9.4	13.1	25	6
Service Hours:				
Type A oil	...	4 500	10 000/14 000	20 000
Type B oil	...	10 200[b]	37 500	30 000[c]
Type B oil	...	11 400	...	...
Type C oil	52 000+[a]	38 000	...	...
Type C oil	...	14 000	...	...
Type D oil	...	800+	...	...

[a] Started on 7 per cent old oil and 93 per cent new oil to prevent rusting. No rust to date.

[b] Started on type B oil before development of rusting test for oils. Rust and sludge found at the end of both runs on type B oil. Put in type A oil which stopped rust at sacrifice of only 4500 hr. before sludge (soft type) developed in oil cooler. Type C oil put in and changed at end of 30,000 hr. as safety feature as steam blew on main oil tank for two years. Second charge of type C oil removed and type D put in after vibration loosened rust and wiped No. 1 bearing.

[c] All three gear units showed gear wear. Changed to type A oil.

Film Strength

Film strength of turbine oils is only of interest in gear lubrication. This property is under investigation in a subcommittee of Technical Committee C.

Little is known by us except that geared turbines Nos. 1, 2, and 6 all showed gear wear when operating on type B oil. Since changing to type A oil and accepting a short service life, the gears are giving normal performance. It is believed that type B oils do not wet the metal as well as type A oil. When sufficient generating capacity is available, it will be interesting to see if type D oil will provide sufficient wetting or film strength to protect the gears. The worm gears driving the main oil pump and flyball governor on direct-connected units are apparently running with a very small factor of safety. In the case of No. 11 turbine, two sets of worm gears wore out in less than 10,000 hr., yet the third set has run more than 50,000 hr. without evidence of cutting. On geared turbines some consideration to separating the oil systems for the generator and turbine, from the gear oiling system, might be of value. We are limited as to what can be done in the case of gear trouble by having to consider the whole machine oiling system as an integral unit.

Turbine and Oil System Data

The data in Table II have been selected as being typical upon which our statements are based. In order to limit the data, not all information is included as the records kept on our turbines cover hundreds of pages. From the date of installation to the present time, all work done, changes made, and reports of observation are available. The records maintained by our Power Department are very valuable as there is no guesswork about the past history. They make a good foundation upon which changes are made in operating procedures.

Conclusions

Various difficulties have been discussed in this paper. We should not lose sight of the thousands of hours of

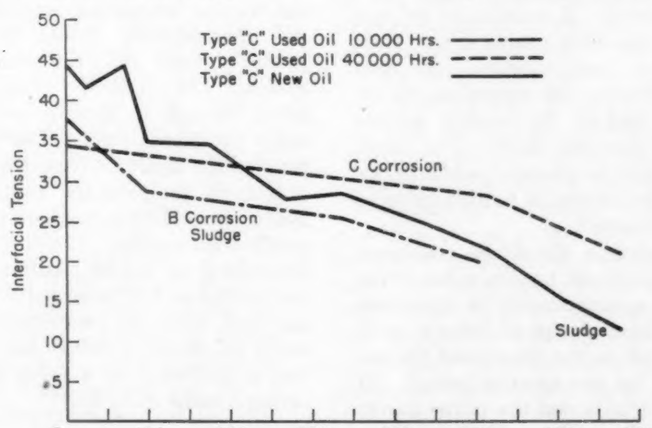

Fig. 2.—Eastman Oxidation-Corrosion Test. New and Used Oil.

successful trouble-free operation. The remarkable progress made in the last 15 or 20 years is excellent testimony to the development work by the turbine builder and the oil companies who have generously given of their knowledge to the user. What appears to be our only source of trouble at the present time is not insurmountable. A quick, easy method of determing oil condition is needed. Frequent inspections are still required in order to insure continuity of service. The experience of users is needed to guide us in our operating practices.

The Care of the Lubricant and Maintenance of the Lubricating System for Central Station Turbine Equipment[1]

By Ernest F. Walsh[2]

In many cases in the past the selection of a brand of lubricating oil for central station turbines has been influenced by facts other than those dictated by good engineering practice. Fortunately, this sort of practice is no longer so prevalent, and operating companies are now basing their decisions, as to the selection of lubricants, on performance records.

Unfortunately, a good lubricant can be placed in a prime mover without necessarily obtaining the desired results. This may be due to several reasons, namely,

1. Improper preparation of the metal surfaces including cleaning and the exposure of the oil to extended metal surfaces,
2. Improper maintenance of the oil during the initial filling of the prime mover lubricating system and during the flushing period,
3. Addition of used oil in varying percentages as a rust preventative, or
4. Improper maintenance of oil during regular operation.

All mineral oils are subject to deterioration by oxidation, and the length and nature of the service they will give will be influenced by the crude oil stock from which the oil was refined, the method of refinement, the type of inhibitor used if an inhibited oil, and the metals in contact with the oil during its service as a lubricant.

If a mineral oil continues to be in contact with iron, copper, and brasses, the rate of deterioration will be accelerated due to their catalytic effect. Longer oil life and years of trouble-free service can be obtained by protecting the lubricant from these known destructive agents.

Before adding a lubricant to a new prime mover, all metal surfaces should be thoroughly cleaned. This can be accomplished by the mechanical removal of mill scale and rust and then thoroughly cleaning the surfaces with solvents. Immediately following the solvent cleaning, all accessible metal surfaces should receive an application of a coating impervious to oil and water. If independent oil coolers are used, the interior surfaces of the shells should receive the same treatment. Oil cooler tube bundles, whether immersed in the oil reservoir or in independent shells, should also receive a protective coating. Other important surfaces that should be protected include the oil reservoir and all metal surfaces contained therein and hydrogen detraining tanks if the generator is hydrogen cooled.

On prime movers which have had years of service with noninhibited oils, a somewhat different cleaning procedure is necessary. Most electrical systems today have limited spare generating capacity, and prime movers cannot be spared for extended cleaning periods. An effective and relatively inexpensive method which will result in a minimum of turbine outage is as follows:

The prime mover should be taken off the line and the lubricating oil drained from the system. The oil reservoir and other accessible stagnant areas should then be cleaned of sludge deposits. The oil should then be placed back in the prime mover which then becomes available for service. A continuous by-pass oil filter using fuller's earth should then be installed and operated for two months. During this operation, the oil from the turbine lubricating system should be sampled daily. The earth charge should be changed when no increase in the interfacial tension value of the oil is observed.

This procedure should be continued until the interfacial tension value of the oil reaches approximately 34 dynes per cm. The final charge of fuller's earth should be left in the filter until the expiration of the two months' period. At the end of this period the prime mover oil system should be sufficiently clean to receive a new charge of oil. Approximately 800 lb. of fuller's earth will be required to clean a system containing 1600 gal. of oil.

Following the cleaning procedure it will be necessary to have the prime mover out of service for a period sufficient to remove the old oil and install the new oil. This should require about 8 hr.

The fuller's earth treatment will cause the oil to be sufficiently solvent to dissolve the sludge in the system which will become entrained in the fuller's earth.

If sufficient time is available such as during an overhaul period, the metal surfaces should receive a protective coating as mentioned under new prime movers.

Metals which have been in contact with oil over a long period will be saturated with oil to an appreciable depth below the surface. Before applying protective coatings, the oil should be removed to a point slightly below the surface of the metal. This can be accomplished by washing the metal surfaces with a high boiling point solvent followed by carbon tetrachloride and immediate application of the protective coating after the solvent has evaporated.

Assuming the lubricating system of a new prime mover is ready to receive its first charge of lubricating oil, the selected lubricant should be removed from the shipping containers and placed in an oil storage or dump tank connected to the turbine lubricating system. Under no circumstances should the oil be placed directly into the prime mover system. The oil should then be circulated through an airtight centrifuge or other equipment that will satisfactorily remove the moisture from the oil. An automatic temperature controlled oil heater should be a permanent part of the purification system. Circulation of the lubricating oil should continue through the purifier and be returned to the storage tank until the temperature of the entire oil charge is 160 F. and moisture free as indicated by a spark test[3] indicating a value of 32 kv.[3]

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at the Symposium on Service Experience with Inhibited Turbine Oils at a meeting of A.S.T.M. Technical Committee C on Turbine Oils of Committee D-2 on Petroleum Products and Lubricants held in Washington, D. C., on February 9, 1948.

[2] Assistant to Superintendent of Power Plants, The Narragansett Electric Co., Providence, R. I.

[3] Tentative Method of Test for Dielectric Strength of Insulating Oil of Petroleum Origin (D 877 - 46 T), 1946 Book of A.S.T.M. Standards, Part III-B, p. 617.

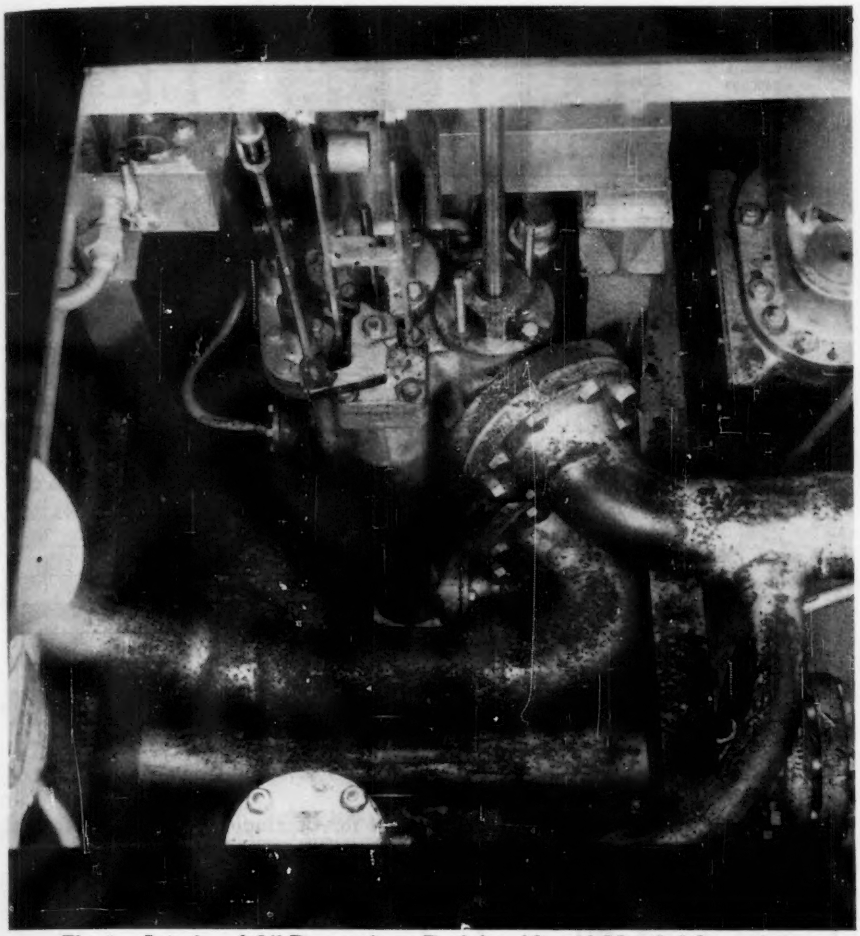

Fig. 1.—Interior of Oil Reservoir on Draining After 3½ Months' Operation.

"Rust barnacles" on horizontal surfaces and pipe lines are shown where they were not painted with a protective coating. These rusted areas had been cleaned by wire brushing, washed with a solvent, and rinsed with carbon tetrachloride. This removed all protective oxidation products, presenting cleaned surfaces easily attached by free water.

Oil contained corrosion inhibitor that passed all A.S.T.M. corrosion tests. No traces of rust were found on finished surfaces or semifinished vertical surfaces.

Before placing the oil in the turbine system, cone strainers should be installed in oil supply lines to all bearings and the governor. The throttle and trip mechanism should be by-passed. If strainers are not permanently installed on oil pump suctions, they should be equipped with fine mesh strainers for the flushing operation.

Water at sufficient temperature to maintain the oil system at 160 F. should be circulated through one of the oil coolers. The system is then ready to receive the lubricating oil charge. The purifier discharge should be transferred to the turbine oil reservoir until it is filled. The oil in the reservoir should then be circulated through the purifier system until its temperature is again 160 F. and has a dielectric strength of 32 kv. After this is accomplished, the purifier should be continued in operation on a by-pass system, the turbine auxiliary oil pump started and the oil circulated throughout the turbine lubricating system, maintaining a temperature of 160 F. by regulating the flow of hot water through the oil cooler. This operation should continue until no deposits appear on the strainers. The strainers should be examined at four-day periods and cleaned if necessary. The flushing operation will consume from seven days to three weeks depending upon the cleanliness of the piping and equipment when installed. In no case should the strainers be removed until the system is clean.

When no further evidence of deposits appears in the strainers, they should be removed, the piping connections made to the throttle and trip mechanism, and the governor dismantled and cleaned.

If the turbine is not ready to be placed in service, the oil should continue to be circulated through the continuous by-pass filter, maintaining an oil temperature of 140 F. Purifiers containing fuller's earth or like materials should not be used. If an inhibited oil is used, the earth filters will remove the rust inhibitors from the oil, and in the majority of oils available, it will also remove the oxidation inhibitors.

It should be remembered that oils containing rust inhibitors can only protect those surfaces submerged in the oil. The surfaces above the oil level, such as in the hydrogen detraining tank and in certain oil reservoirs, will be in contact with oil and water vapors if the oil contains any moisture, and rusting is bound to occur unless the metal surfaces are coated with a protective film.

Figure 1 shows an oil reservoir on a 50,000-kw. unit after 3½ months' operation. Note the rust barnacles on the surfaces below the oil level. The oil in this case was not dried before being placed in the unit nor were the system areas below the normal oil level coated with a protective coating. The oil was a good grade, rust and oxidation inhibited.

Upon finding this condition, the oil was removed from the system, all accessible metal surfaces cleaned and protective coated, the oil dried and returned to the system. The unit has since completed seven years of operation without any further indication of rusting or oil deterioration.

After a unit is placed in operation, the lubricating oil must be maintained in proper condition to obtain dependable operation and long oil life. This is a simple accomplishment if a definite program is outlined and maintained. It is essential that the lubricating oil in the system be continuously free of moisture and solids such as fly ash and other dust particles common to the atmospheres prevailing at times in power plants. This can best be accomplished by operating a purifier on a continuous by-pass system.

In addition, a graph should be prepared (Fig. 2) showing the essential test values such as interfacial tension, saponification number, and viscosity. Cumulative records of oil makeup and differential oil temperatures are also helpful in analyzing the oil performance. Samples should be taken from the system each month and the results of the analysis promptly plotted for the maintenance of up-to-date records.

The lubricating oil used in the prime mover is also a proper lubricant for almost all of the boiler and turbine auxiliaries. Oil for the auxiliaries should be obtained from the turbine system and all station makeup of that grade of oil added to the turbine system. By this procedure the oil in the turbine is maintained at a constant quality value, likewise the oil used for auxiliary lubrication.

There has been considerable discussion as to the relative merits of rust and oxidation inhibited oils *versus* noninhibited oils. The comparative results obtained from accelerated oxidation

tests give a ratio of 10 to 1 in life in favor of a good inhibited oil; that is, an inhibited oil produced from a good crude oil stock and well refined before being inhibited. Little is gained by adding inhibitors to a poor grade of lubricating oil.

In actual practice, inhibited oils have produced excellent performance records. If the system is maintained dry and catalytic materials coated, the life of the oil appears to be indefinite.

Inhibited oils after seven years of continuous service do not show any measurable deterioration as indicated by the interfacial tension value which is a measure of the polar molecules present and therefore a true measure of deterioration.

The use of inhibited oils eliminates the necessity for periodic draining and resting of turbine oils and the use of fuller's earth filters. They likewise maintain a clean system and an oil free of sludge which in turn reduces the friction losses on the unit.

The operator soon becomes convinced that the lubricating oil in the turbine system is no longer something he must be concerned about and can divert his attentions to other items important in maintaining high efficiency in his station.

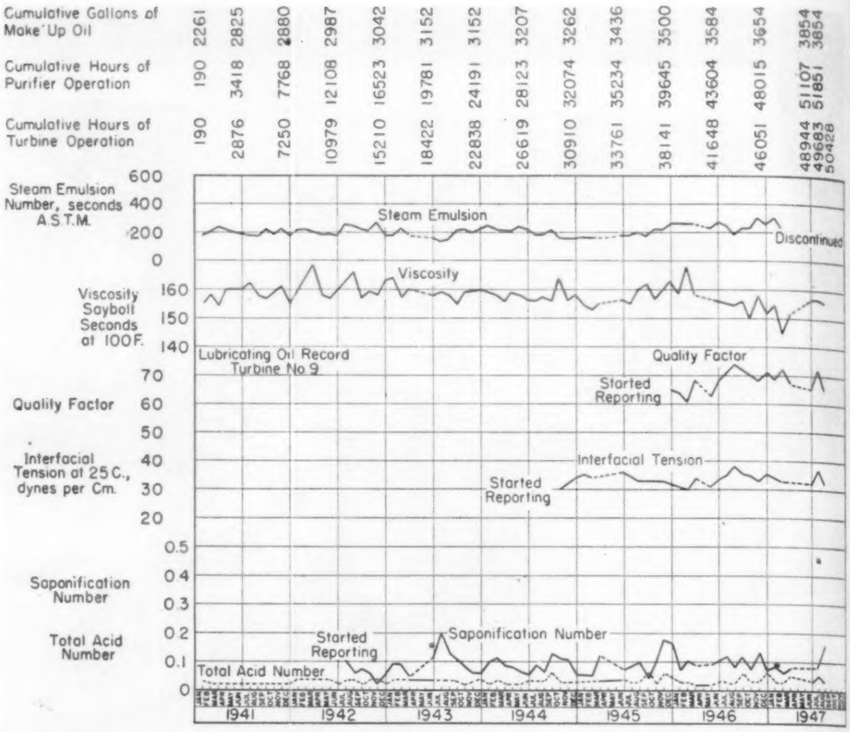

Fig. 2.—Chart Showing Essential Data Required for Continuous Operating Record of Turbine Lubricating Oil.

Steam Turbines and Their Lubrication[1]

By C. D. Wilson[2]

THE steam turbine is a prime mover. It is never operated alone but is always used to drive other equipment. Although it can be designed to operate at any speed required by the driven member, a high-speed turbine is more economical to build and operate. Reduction gearing is, therefore, almost always used for low-speed drives such as ship propellers, large pumps and other similar equipment. Where the speed of the driven member is approximately 1500 rpm. or higher as on electric generators, boiler feed pumps, or blowers, it is usually coupled directly to the turbine without gearing.

The steam turbine is unique in that it is being built today in the greatest range of power capacity of any of the prime movers. The sizes built cover a range from small fractional horsepower turbines to cross compound generator units larger than 200,000-kw. capacity. The different types of equipment using the steam turbine for motive power include a-c. generators, d-c. generators, pumps, blowers, fans, ships, and railroad locomotives. The greatest application is in driving alternating current generators and almost 70 per cent of the total electric power generated in the United States today is obtained from generators driven by steam turbines. This represents, according to a recent survey, slightly over 34,000,000 kw. of installed generating capacity.

Ship propulsion is next in importance to the generation of electric power. Steam turbines are used to drive ship propellers either directly through reduction gearing or indirectly through turbine-driven generators and motors. In the U. S. Merchant Marine the total turbine shaft horsepower today approximates 18,000,000 shp., and, of this, about 71 per cent is gear drive and 29 per cent is turbine electric drive.

Turbine Oil Must Suit Turbine Operating Conditions

Gear and Bearing Loads:

The conditions under which steam turbines have to operate have a direct effect on the specifications for the steam turbine lubricant. A steam turbine is either directly connected to the machinery it is driving or it is connected through reduction gearing. On all direct-connected units, the specification for lubricating oil viscosity is governed by the requirements of the turbine sleeve bearings, and, with few exceptions, a turbine oil having a viscosity of 150 Saybolt Universal Seconds at 100 F. can be used. On gear drives, this must be modified to suit the requirements of the gears and a higher viscosity oil is required depending on the size and type of gears used. Oil viscosities, as recommended by various turbine and gear manufacturers, are shown in Table I.

Water in Lubrication System:

Modern turbine design reduces the possibility of condensed steam escaping

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[1] Presented at the Symposium on Service Experience with Inhibited Turbine Oils at a meeting of A.S.T.M. Technical Committee C on Turbine Oils of Committee D-2 on Petroleum Products and Lubricants held in Washington, D. C., February 9, 1948.

[2] Steam Turbine Dept., Allis Chalmers Manufacturing Co., Milwaukee, Wis.

TABLE I.—RECOMMENDED OIL VISCOSITY.[a]

Manufacturer		A	B	C	D	E
Saybolt Universal Viscosity at 100 F., sec.	Direct-connected	140–200	140–170	140–260	...	140–150
	Geared generators	250–350	280–340	250–375	300–350	250–350[b]
	Marine propulsion	400–500	400–500	400–500	450–500	350–550

[a] Data supplied by Allis-Chalmers Mfg. Company, DeLaval Steam Turbine Co., Falk Corp., General Electric Co., and Westinghouse Electric Corp.
[b] Single reduction gears up to 3000 hp.

through the shaft seals and entering the lubrication system in the form of moisture, since newer turbines are equipped with improved seals, mechanical slingers, and gland exhauster systems. Many of the older turbines did not have these features, and, even on the newer ones, there is always the possibility of faulty operation or mechanical failure which would permit water to enter the oil. Water can also enter an otherwise dry lubrication system by condensation of atmospheric moisture on the walls of the reservoir, pedestals, and drain piping. The fact that, at some time or other, water may enter the lubrication system demands that turbine oils have good water separation characteristics and that they have the property of protecting ferrous metals against rusting in the presence of moisture.

Proximity of High-Temperature Steam:

The trend in modern steam turbines is toward higher steam temperatures and turbines for operation with steam at 1050 F. are now under construction. These high temperatures in close proximity to turbine bearings obviously require the use of oils having high flash and fire points.

Air in Lubrication System:

The high surface speeds in sleeve type bearings (up to 220 ft. per sec.) and the high pitch line speeds in turbine-driven reduction gears (up to 300 ft. per sec.) results in considerable intermixing of air with the oil inside bearing pedestals and gear cases. This requires that turbine oils have nonfoaming characteristics and that they permit the entrapped air to separate readily and quickly from the oil during the time the oil is flowing back to the reservoir and before it is again recirculated by the pumps.

Control of Heat in Journals:

The oil used in a turbine is required to do many things in addition to lubricating bearings and gears. Considerable frictional heat is developed in running large high-speed bearings, and most of the oil circulating through the bearing is used to carry away this heat. The heat conducted to bearings through the shaft from the high-temperature steam is also removed by circulating sufficient oil through the bearings to keep the bearing temperature from exceeding a safe value. To prevent excessive oil oxidation, oil flows to bearings are adjusted to maintain oil discharge temperatures from bearings that seldom exceed 160 F. maximum. Table II gives present-day practice for oil temperatures and pressures in the lubrication system.

Hydraulically Operated Control Gear:

Turbine oils are also used as the operating medium for the control gear operating the steam inlet valves, the emergency stop valve, and other regulating and control devices used on the turbine. The safe and reliable operation of these control devices demands the use of an oil that is stable and without tendency to form sludges and deposits or allow rust to form that would interfere with the operation.

Oil Film Hydrogen Seals:

On machines driving hydrogen cooled generators, the gas is sealed inside the generator housing by an oil seal at the points where the rotor projects through the ends of the stator housing. Various types of seals are used but they all depend on a thin continuous film of oil to hold the hydrogen pressure which, on present-day machines, is about 15 psi. maximum.

A Typical Turbine Lubrication System

The utmost reliability in operation is required in practically all applications where steam turbines are used, and turbine manufacturers design their machines to achieve this end. The lubrication system on a steam turbine is no exception to this rule. A typical lubrication system for a steam turbine generator unit is shown diagrammatically in Fig. 1.

Oil Reservoir:

The oil reservoir or oil tank on machines of this type is usually fabricated from steel plates. The tank has a sloping bottom and a large cleanout drain hole located at the lowest point. An exhaust fan system is connected to the high point in the reservoir, above oil level, to draw off vapors and discharge them to an atmospheric vent. All return oil is collected in a strainer compartment and discharged through strainer screens to the main body of the reservoir. Oil reservoirs are usually designed to make the oil circulate back and forth between the return inlet and the pump suctions so as to avoid stagnant areas and, at the same time, give the circulating oil the maximum possible time to settle out impurities and free itself from entrapped air. Oil reservoirs are located in various places with respect to the turbine, depending on the design of the machine. When oil pumps driven from the turbine shaft are used, the reservoir can be located below the floor at either the high-pressure end of the turbine or below the outboard bearing at the generator end. When separate motor-driven pumps are used, the reservoir can be located away from the turbine at any convenient location near or below the turbine floor or in the basement. In a few cases, the reservoir and pumps are located in a separate completely enclosed room so as to isolate the oil system in case of fire. Modern oil reservoirs are provided with manholes to give access for cleaning, and some of the newer reservoirs are streamlined on the inside to permit easier cleaning and to allow sediment to gravitate more easily to the lowest point.

Oil Circulating Pumps:

Gear pumps or centrifugal pumps are types most commonly used for circulating turbine oil. The main pumps are driven either directly from the turbine shaft or through worm gears, helical gears, herringbone gears, spiral bevel gears, or by various combinations of these gears. Sometimes they are driven by separate motors. Oil pressures for governor control vary between about 50 psi. and 150 psi. and for the supply to bearings and gear sprays between about 5 psi. and 25 psi. The main pumps are backed up by one or more auxiliary pumps, either steam turbine or motor driven. These auxiliary pumps are used when starting or stopping or when the main unit is on the

TABLE II.—OIL PRESSURES AND TEMPERATURES.[a]

Manufacturer		A	B	C	D	E
Supply temperature, deg. Fahr.	Turbines	100–120	110–120	115–130	...	110
	Gears	...	110–120	115–130	100–130	110
Oil reservoir temperature, deg. Fahr		120–130	130	130–140	...	Less than 140
Max. expected operating temperature, deg. Fahr.	Direct connected	160	160	160	...	155
	Geared	...	160	180	180	155
	Special	...	180	200	195	....
Supply pressure, psi.	Bearings and gears	5–10	10–25	10	5–15	12–15
	Relay system	50–80	55–150	50–110	...	140

[a] Data supplied by Allis-Chalmers Mfg. Company, DeLaval Steam Turbine Co., Falk Corp., General Electric Co., and Westinghouse Electric Corp.

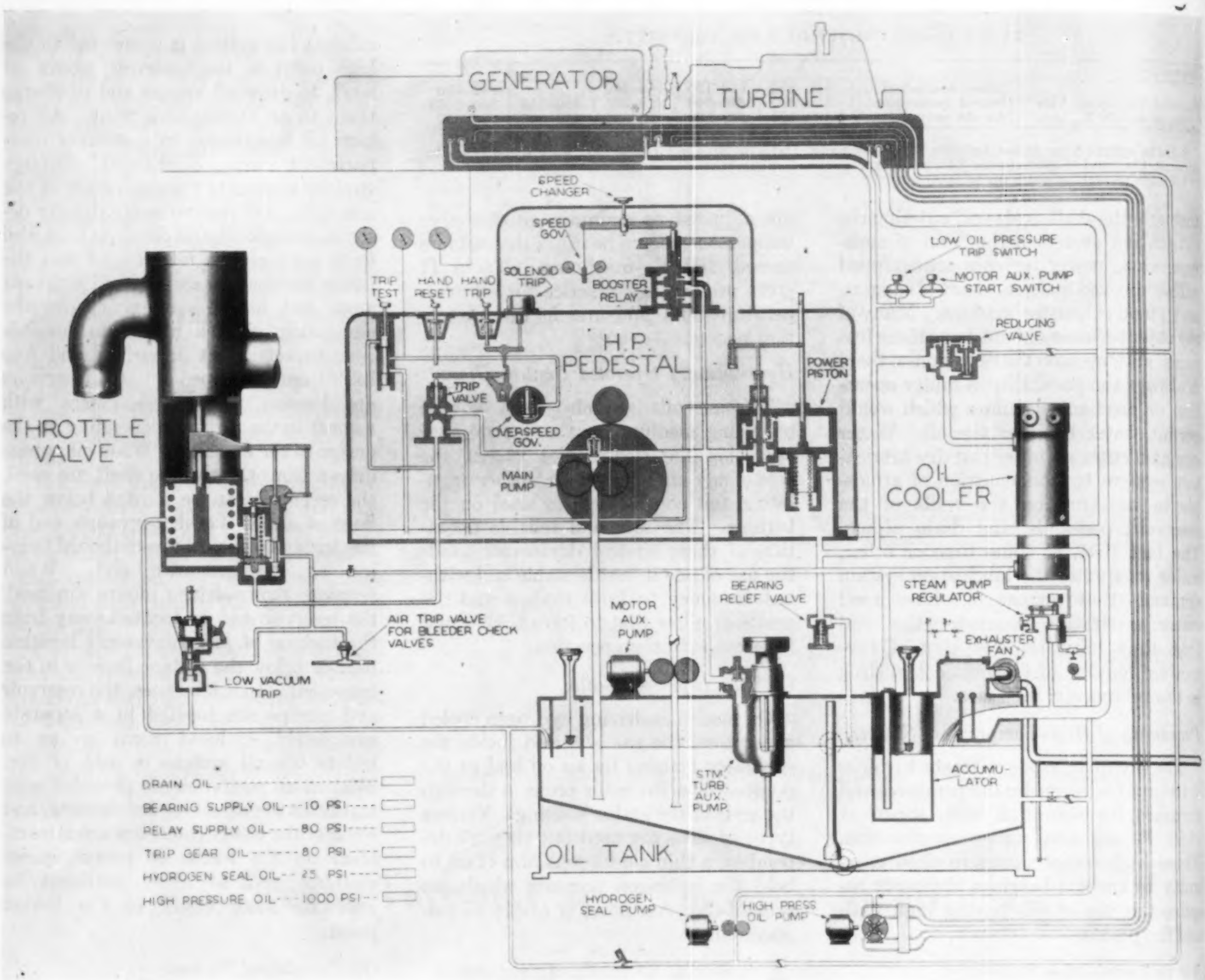

Fig. 1.—Lubrication System for a 20,000-kw. Steam Turbine Generator Unit.

turning gear. (Turning gear operation is explained later.) They are equipped with regulators which start them automatically when the oil pressures drop below a minimum safe value. Low oil pressure alarms are often installed to warn the operators when the oil pressure becomes too low, and on many machines the turbine is automatically stopped by a tripping device actuated by loss of oil pressure. The maintenance of the flow of oil to the bearings is of vital importance, and if the flow of oil should cease, a large turbine could not be stopped quickly enough to prevent wiping the bearings and doing other serious damage. An interesting refinement used on some machines is the high-pressure lift pump which floats the shafts on a film of oil so as to permit easier starting and to protect the bearings against wiping at low speed. Rotors and spindles weighing many tons can easily be rotated by hand during inspection when the high-pressure lift pumps are in operation.

Turbine Journal Bearings:

Sleeve type bearings lined with tin-base babbitt are used, almost without exception, for main turbine bearings. During normal operation, these bearings operate with fluid film lubrication and boundary lubrication conditions do not exist except at very low speeds when starting and stopping the machine. Maximum loads on these bearings seldom exceed 220 psi. of projected area and improved design and manufacturing processes have reduced operating troubles with this type of bearing to practically zero. The rate of oil flow to bearings is proportioned to keep the bearing temperatures within specified limits and is regulated either by orifices in the feed lines to the bearing or by oil slots in the babbitt and clearance between the bearing and shaft. To illustrate what turbine oils have to do in lubricating the bearings on modern turbines, a 3600-rpm. machine with a 50,000-lb. rotor has been in practically continuous operation during the past 10 years. The surface speed of the rotor bearings on this machine is 145 miles per hour. During this time, the 50,000-lb. rotor has sheared an oil film in the bearings only a few thousandths of an inch thick for a linear distance of over 11,000,000 miles. The original oil has never been changed, and its condition today is practically the same as when it was first installed 10 years ago.

Turbine Thrust Bearing:

Thrust bearings, used to locate rotating shafts in proper axial position and to absorb unbalanced thrust of gears and blading, are, in most cases, either the taper land or the Kingsbury tilting shoe type. The maximum designed operating loads on these bearings vary between 250 and 450 psi., but these bearings can safely carry considerably greater loads. The data given in Tables III, IV, and V indicate present-day turbine and turbine-driven reduction gear practice for maximum designed loads on journal bearings, thrust

TABLE III.—MAXIMUM OPERATING LOADS AND SURFACE SPEEDS—JOURNAL BEARINGS.[a]

Manufacturer		A	B	C	D	E
Load on projected area, psi.	Turbines	225	250	175	...	200
	Gears	...	250	250	300	200
Surface Speed, ft. per sec. (turbines and gears)		212	220	170	200	200

[a] Data supplied by Allis-Chalmers Mfg. Company, DeLaval Steam Turbine Co., Falk Corp., General Electric Co., and Westinghouse Electric Corp.

TABLE IV.—MAXIMUM OPERATING LOADS—KINGSBURY OR TAPER LAND THRUST BEARINGS.[a]

Load on projected area, psi.	Turbines	250	450	250	...	250[b] 400[c]
	Gears	...	450	350	300–350	...

[a] Data supplied by Allis-Chalmers Mfg. Company, DeLaval Steam Turbine Co., Falk Corp., General Electric Co., and Westinghouse Electric Corp.
[b] 1800 r p m.
[c] 3600 r p m.

TABLE V.—MAXIMUM LOAD, *K* FACTOR AND MAXIMUM PITCH LINE SPEED—DOUBLE REDUCTION HELICAL GEARS FOR MERCHANT MARINE SERVICE.[a]

Manufacturer		A	B	C	D
Pressure per inch of face, lb.	1st reduction	500	600	500–600	....
	2nd reduction	1 000	1 200	900–1100	....
K Factor[b]	1st reduction	90	100	85–95	100
	2nd reduction	70	75	65–75	70
Ft. per min. at pitch line	1st reduction	15 000	18 000	16 000	13 800
	2nd reduction	7 000	9 000	10 000	

[a] Data supplied by DeLaval Steam Turbine Co., Falk Corp., General Electric Co., and Westinghouse Electric Corp.

[b] K factor $= \frac{w}{d}\left(\frac{R+1}{R}\right)$ where w = pressure per inch of face, d = diameter of pinion, R = D/d, and D = diameter of gear.

bearings and reduction gears and maximum surface speeds on sleeve type journal bearings and pitch line speeds of helical gears.

Oil-Operated Controls:

An essential and very important function of the turbine lubricating oil is its use as the hydraulic medium to operate the valve gear and automatic safety controls on a steam turbine. By using oil at pressures varying between 50 psi. and 150 psi. to operate hydraulic pistons, forces as high as 20,000 lb. can be developed to move the high-pressure steam valves. The steam valves have to move in a fraction of a second in order to maintain the close regulation required, and the valve gear mechanism has to be reliable and free from operating troubles because, when it is called upon to act, it has to respond instantly to prevent overspeeding and wrecking the machines. On some low-inertia machines sudden loss of load could cause the unit to accelerate in less than one second to a disastrous overspeed unless the oil-operated governors were there to prevent it. The almost instantaneous operation of the various hydraulic control gear on a steam turbine demands a supply of high-pressure oil instantly available in the required volume. This demand is met by using various types of air or spring loaded accumulators or by using a centrifugal pump which has the characteristic of delivering an increased volume of oil with a slight drop in pressure. Also, since the quickest operation is required in the direction of closing the valves (where the actual forces required are low) a two diameter power piston is often used so that the smaller piston, which displaces less volume of oil, can move quickly to close the valves. Even with all this, on some large high-speed topping turbines, having low inertia, it has been considered desirable to provide an additional inertia governor that would start closing the steam inlet valves before the tripping speed (where the emergency governor starts to act) is reached.

Turbine Governor:

The turbine governor, which regulates the opening of the steam admission valves to maintain normal speed, is usually a mechanical flyball type governor or a centrifugal impeller type which regulates by the variation in hydraulic pressure developed with variations in impeller speed. In either case, the actual motivating forces generated in the governor are relatively small and these forces have to be amplified by a hydraulic relay system.

Turning Gear:

A motor-driven turning gear, which is used to rotate the turbine shafts at slow speed when the machine is out of service, is furnished as standard equipment on turbines 10,000 kw. and larger. This equipment is necessary because, if the turbine shafts remain stationary during the cooling-off period following a shutdown, the shafts would distort and bow due to the uneven distribution of temperature inside the casing.

A turbine with a bowed shaft cannot be brought up to speed without excessive vibration, and, without a turning gear, it would be necessary to run the machine with steam at very slow speed for many hours in order to straighten the shaft. Present practice is to put the machine on the turning gear immediately after a shutdown so that the shafts will not distort. By keeping the shafts straight, the machine can be put back in service in the shortest possible time when it is again needed.

The turning gear is always used when starting a turbine, even though the machine is cold, and standard practice is to run on the turning gear until the shafts run true before admitting steam and bringing the machine up to speed. Turning gear speeds vary between 1 rpm. and 30 rpm. depending on the design and make of turbine. Even though the higher turning gear speeds maintain a better oil film in the turbine bearings, it is considered good practice always to use the oil coolers during turning gear operation so as to increase the oil viscosity and give the babbitt bearings added protection against wiping.

Piping, Reducing Valves, Relief Valves, Coolers, and Filters:

Other essential parts of the steam turbine lubrication system include reducing valves which automatically maintain the desired oil pressures, relief valves which discharge surplus oil back to the reservoir, oil coolers which remove the excess heat from the oil, and oil filters that remove sediment, sludge and other contamination from the oil. All parts of the lubrication system are connected by piping which, on modern turbines, is usually seamless steel with welded flanged connections. Oil velocities through the pressure feed lines vary between 5 and 15 ft. per sec. All drain lines are sloped and drain back to the reservoir by gravity. Drain pipes sizes are proportioned so that they run about one half full to allow for natural venting.

Oil System Capacity and Rate of Circulation

Turbine lubrication systems are designed so that all of the oil in the system passes through the pumps between once every five minutes and once every ten minutes. Table VI indicates present-day practice for system capacity and rate of circulation for various size turbine generator units.

Requirements of an Ideal Turbine Oil

Before concluding this brief description of the steam turbine and its lubrication system, I should like to review the requirements of a theoretically ideal turbine oil.

1. Stability.—A turbine oil should be stable and not deteriorate in service. Modern turbines have a very small rate of makeup and the initial charge of oil should last for the life of the turbines.

TABLE VI.—OIL SYSTEM CAPACITIES AND PUMPING RATES.[a]

Kw.	Rpm.	Oil capacity			Pumping Rate, gal. per min.					
		System		Tank	Normal			Maximum[b]		
Manufacturer		A	B	C	A	B	C	A	B	C
500..	3 600	...	...	100	...	...	50	...	...	100
1 500..	3 600	...	...	225	...	...	50	...	...	100
2 500..	3 600	450	420	300	60	60	50	60	60	100
5 000..	3 600	450	600	400	90	90	95	90	90	200
10 000..	3 600	710	900	900	120	130	125	120	130	350
20 000..	3 600	1 420	1 700	1 250	227	160	145	227	160	400
25 000..	3 600	...	...	1 500	...	...	150	...	...	400
30 000..	3 600	1 420	2 150	2 000	252	175	180	252	574	525
40 000..	3 600	2 500	2 150	2 000	325	235	300	325	635	750
60 000..	3 600	2 500	2 750	2 500	396	250	400	396	830	925
100 000..	3 600	3 400	3 150	3 000	440	325	450	440	830	1 200
50 000..	1 800	...	2 750	...	...	290	...	...	830	...
75 000..	1 800	...	...	2 500	...	...	475	...	...	1 163
80 000..	1 800	...	3 150	...	...	290	...	...	830	...
100 000..	1 800	5 400	...	3 000	620	...	500	620	...	1 500
150 000..	1 800	7 500	...	...	775	...	...	775	...	...
165 000..	1 800	...	...	4 000	...	...	600	...	...	1 500

[a] Data supplied by Allis-Chalmers Mfg. Company, General Electric Co., and Westinghouse Electric Corp.

[b] Pumping rate given in column A is supplemented by oil accumulator to meet maximum flow requirements. Where pumping rates given in columns B and C are greater than normal pumping rate, the higher values are due to use of centrifugal pump.

Turbines have been operated without shutdown for periods considerably in excess of the normal two years between scheduled inspections. A good turbine oil should always be in such condition that when the turbine is put back into service there will be no doubt but that the oil will last until the next scheduled shutdown.

2. Water Separation and Rust Protection.—A turbine oil should separate freely from water, and, if water should accidentally be present in the lubrication system, the oil should protect ferrous surfaces from rusting. Most modern turbines are inherently dry and free from moisture in the lubricating system, but accidental entry of moisture is often unavoidable and the possibility of condensation is always present so that the ability of a turbine oil to separate from water and protect against rusting is essential.

3. Viscosity and Viscosity Index.—Viscosity can be easily controlled to meet specifications, and viscosity index can be regulated to a certain extent without too much difficulty. Too flat a viscosity index curve is not desirable because some change of viscosity with temperature is necessary to regulate automatically the operating oil temperature without having to install special thermostatic controls. It appears that present values of viscosity and viscosity index are satisfactory.

4. Anti-Foaming Tendency and Air Separation.—A turbine oil should not foam and should allow air that becomes intermixed with the oil to separate rapidly and completely. On high-speed turbines, a certain amount of air is unavoidably mixed and trapped in the oil. If foaming occurs, it interferes with proper drainage of the system, and, in extreme cases, overflows and causes considerable nusiance and possible hazard. Entrapped air reduces the density of the oil and may affect the operation of the hydraulic control system. The necessity of nonfoaming oils that permit rapid and complete separation of air is obvious.

5. Film Strength.—Turbine oils require high film strength properties for lubrication of gear teeth under load and to prevent wiping of bearings when boundary lubrication exists during starting and stopping. Some additives to improve this property may be desirable in that they would allow increasing the load capacity of present designs of gears and bearings. As far as is known, there has not been too much difficulty from lack of this property in present-day turbine oils.

6. Specific Heat.—Because a turbine oil is used to remove surplus heat from bearings and gears, an oil with a high value of specific heat would do this job more efficiently. On present machines, the rate of oil circulation is far in excess of that required for lubrication, and the quantity of oil circulated is adjusted to control operating oil temperatures. If the value of specific heat could be raised, the oil circulation rate could be reduced.

7. Flash and Fire Points.—In turbine oils, the higher the flash and fire point the better. This is becoming more important with increase in operating steam temperatures and with present turbine oils the only control is to circulate enough oil to keep the temperatures down to a safe value.

Turbine Design Paced by Oil Improvements

The steam turbine and its lubricating system is a highly complex aggregation of specialized equipment, and it has been impossible, in the short space available, to more than briefly describe some of its functions and design features. In this paper the importance of the lubrication system to the successful and reliable operation of the steam turbine has been emphasized. A large turbine generating plant often represents an investment of over $10,000,000 and this type of plant just cannot afford to be shut down because of faulty operation of the lubricating system or breakdown of the lubricating oil. The turbine builders are designing and building turbine lubrication systems with a structural strength far in excess of what is actually needed for the pressures to be handled. The lubricating system includes many kinds of automatic devices and controls to safeguard against failure of one or more of the essential operating parts, and the detailed design of all operating parts has been strengthened and perfected through years of operating experience to increase reliability and reduce the possibility of mechanical failure.

The improvements that have been made in turbine design are being matched by the oil companies in their development of the modern inhibited turbine oils. The net result of these parallel developments is a turbine lubrication system that requires less maintenance and, at the same time, gives longer and more reliable operation between scheduled inspections.

Acknowledgment:

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The Thixotropic Characteristics of Lubricating Oil Greases

Report from Section IV on Pacific Coast Research of A.S.T.M. Technical Committee G on Lubricating Grease of Committee D-2 on Petroleum Products and Lubricants

Prepared by L. W. McLennan[1] and G. H. Smith[2]

Synopsis

A preliminary study has been made of the thixotropic characteristics of lubricating oil greases and of the various means of evaluating them in this respect. Certain regular relationships have been developed in relation to the breaking down of greases under shearing action and to the healing of greases after breakdown. Such relationships have interesting potential applications in research and lubrication practice.

The greases used in this work included sodium, calcium, aluminum, lithium, and barium base greases.

The regular relationships developed in the work raise a question as to the validity of the concept of yield point.

The time factor involved in thixotropy has been considered in respect to the flow of greases through pipes and its effect in this respect has been evaluated.

Most lubricating oil greases, if not all, possess thixotropic characteristics in some degree. For the convenience of the reader, the following definition of thixotropy, in reference to greases and consistent with authoritative definitions (**1**, **2**),[3] is offered:

Thixotropy in greases is that property which is manifested by a decrease in consistency as a result of working, followed by an increase in consistency starting immediately after working is stopped.

From this definition, it is seen that thixotropy involves the factors of time and reversibility. Since an understanding of this property of greases can be of interest from the viewpoint of both research and practice, it is surprising that the matter has received so little direct attention in the past. Technical Committee G on Lubricating Grease of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants, recognizing this fact, initiated a preliminary study of the subject through one of its subcommittees, and the matter presented in this paper represents the results of the work to date.

Thixotropy is encountered in many different types of materials other than greases, for example, paints, printing inks, rubbers, muds, clays, and glues. The thixotropic characteristics of a grease constitute in a sense an expression of its composition and structure, and consequently an understanding of its thixotropic behavior can be expected to reveal some additional knowledge on the complex nature of the grease. However, the present study was not projected upon this basis but rather upon that of practical application.

To illustrate that thixotropic behavior is familiar under other names, one has only to refer to the hardening of greases in storage or in centralized lubrication systems, or to the breaking down or softening of greases under shearing or milling action. Thus, most persons associated with the grease industry are familiar with the manner in which this property manifests itself. In view of the foregoing, it is clearly desirable to understand the basic principles governing the thixotropy of greases so that it will be possible to establish methods of measuring, predicting, and controlling the behavior of greases in this respect.

Materials

The greases employed in this investigation were of the conventional types including sodium, calcium, aluminum, lithium, and barium base greases. The selection was based chiefly upon the convenience of the cooperating laboratories since the program was drawn primarily to develop basic information and principles. Data pertinent to the greases are summarized in Table I.

Methods

It is clear from the definition of thixotropy that methods employed in the investigation should be such as to permit one to follow the breakdown and the healing of a grease with time. In addition, methods must be sufficiently flexible to allow an evaluation of the variables that might affect these processes. Three general methods have been used to date and these methods are described in the following paragraphs.

Penetration Methods:

These methods involve the obtaining of penetration values on samples of greases after they have been worked or sheared under specified conditions, for example in an A.S.T.M. grease worker, for definite time intervals. Either the A.S.T.M. penetrometer[4] or the Shell micro penetrometer (**3**) may be used depending upon the quantity of sample available. Values by the latter method can be converted to those by the former method if desired (**3**).

These greases were milled in a grease kettle or A.S.T.M. grease worker, or by means of a gear pump which recirculated the grease to a hopper attached to the feed side of the pump. Samples were tested at appropriate intervals during the milling operation in order to follow the extent and rate of breakdown. As soon as the breakdown operation was stopped, samples were taken immediately and stored under controlled conditions for definite time intervals. Linear relationships were obtained for rate of breakdown and rate of healing when the data were plotted on logarithmic scales. Since greases heal at a fast rate initially, as soon as the milling action stops, the

TABLE I.—CHARACTERISTICS OF LUBRICATING OIL GREASES.

Grease	Soap		A.S.T.M. Penetration at 77 F. (Worked)	Mineral Oil Characteristics		
	Type	Per cent		Viscosity, SUS at 100 F.	Viscosity Index	Type
A	Aluminum	6.5	340	1200	...	California
B	Sodium	22.0	325	300	...	Midcontinent
C	Barium	10.0	335	450	58	
D	Lithium	14.0	298	200	16	
E	Calcium	10.0	325	200	30	
F	Aluminum	7.0	262	600	22	
G	Barium	18.5	245	500	48	California
H	Lithium	9.0	270	1050	−22[a]	
J	Sodium	10.0	315	300	33	
K	Calcium	19.0	230	220	30	

[a] Contains asphaltic or black oil.

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[2] Research Chemist, Union Oil Co. of California, Oleum, Calif.

[3] The boldface numbers in parentheses refer to the list of references appended to this paper.

[4] Tentative Method of Test for Cone Penetration of Lubricating Grease (D 217 – 47 T), 1947 Supplement to Book of A.S.T.M. Standards, Part III-A, p. 139.

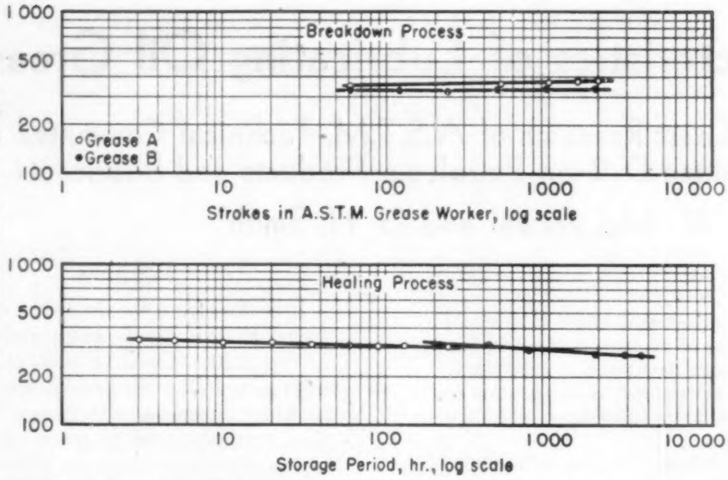

Fig. 1.—The Breakdown and Healing Processes for an Aluminum Grease (Grease A) and a Sodium Grease (Grease B).

penetration values were obtained as soon as possible after the working of the grease had been terminated. In obtaining penetration values on aged samples a precaution found to be necessary was to avoid any disturbance of the test sample, otherwise the grease might be softened and erroneous data result. The necessity of such care is illustrated by the following observation. Samples of several greases were stored undisturbed for two years, and it was noted that merely stirring these samples with a thermometer raised their penetration over 100 points. When the precaution described above was observed, check values within several points could generally be obtained.

Data obtained using penetration methods are presented graphically in Figs. 1 and 2.

Method Using Measurement of Power Requirement:

In following the breakdown process in the grease the penetration methods do not permit a series of instantaneous and continuous determinations. A convenient method of making such measurements involves measuring the power requirement of the mechanical grease worker during the breakdown process. The power required to operate the worker without a grease charge is large (approximately 135 w.) compared with that needed to work the grease, thus reducing the sensitivity of the test. Consequently, only heavy greases can be evaluated satisfactorily by this method. For example, one type grease of National Lubricating Grease Institute No. 2 grade showed a change in net power requirement from 18 to 3 w. during a working cycle of 5000 strokes. On the other hand, another type grease of N.L.G.I. No. 4 grade showed a change from 79 to 24 w. for 1000 strokes. Data for this latter grease are presented graphically in Fig. 3.

Although the above method may be superior to penetration methods for following the breakdown, since measurements are almost instantaneous, it is not satisfactory for an extended test because of lack of temperature control. In addition, the wattage change is too small in some cases to be significant.

Method Using Capillaries:

The third method used in studying the thixotropy of greases involves the circulation of a grease in a closed system as shown in Fig. 4. The unit consists of a 5-B Zenith constant-displacement pump connected to the capillary by $\frac{1}{4}$-in. pipe. A pressure gage and thermocouple are installed at each end of the capillary, which is a short length of $\frac{1}{4}$-in. copper tubing. During the circulation period, the system is open to a reservoir of grease which acts as a surge tank. Air pressure maintains a steady flow of grease to the pump. The whole apparatus, with the exception of the pump, can be immersed in a water or oil bath in order to maintain constant temperature. In future work, the apparatus will be remodeled to permit its complete immersion including the pump.

The volume and length of the capillary were measured and the average diameter determined. The rate of shear, arbitrarily designated by Arveson (4) as being the value of the expression $4Q/\pi R^3$, could then be calculated for any given flow rate. From gage readings, the pressure drop across the capillary was obtained. The apparent viscosity was calculated from this pressure drop by Poiseuille's equation (5) $\eta_a = \pi PR^4/8LQ$, where the symbols have the significance defined in the nomenclature section at the end of this paper. The values for the apparent viscosity give straight lines when plotted logarithmically against the time of circulation.

Using the capillary unit, such factors as the rate of shear, the time of working and storage, and the temperature can be varied to study their effects on the thixotropy of greases. Data obtained for the different greases are shown graphically in Figs. 6, 7, 8, and 9.

Experimental Data

The Healing Process:

As a matter of convenience, the healing process in the worked grease is discussed before the breakdown process. In following the healing process, the penetration method was the principal one employed. The data obtained for sodium, aluminum, lithium, calcium, and barium greases are presented in Figs. 1 and 2. Penetration values were plotted logarithmically against time of healing and a linear relationship obtained. A linear relationship appears to be general for both the breakdown and healing processes irrespective of the method used. In the case of some barium greases, the healing period has been extended as long as 25 months, while in the instance of other types of greases the healing periods have ranged as high as 30 to 40 days. The amount of healing that occurs within a measured time can also be estimated by allowing the worked grease to remain undisturbed in the viscometer for a specified time before

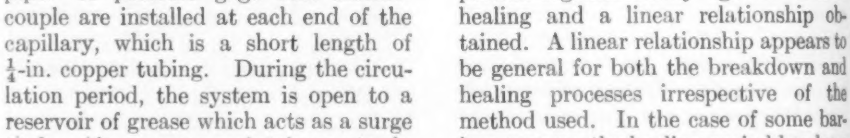

Fig. 2.—Healing Process for Various Type Greases.

TABLE II.—PRESSURE DIFFERENTIALS OBTAINED USING A BARIUM GREASE (N.L.G.I. 1 GRADE) DURING CONSECUTIVE PERIODS OF CIRCULATION.[a]

Time, sec.	Pressure Drop Across Capillary, p.s.i.								
	Tests at 32 to 34 F.[b]					Tests at 72 to 75 F.[c]			
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4
10	303	...	165	160	...	64	61	63	63
20	151	...	145	...	...	63	....	61	....
30	147	143	143	140	...	62.5	60	....	62
40	145	...	...	139	...	....	....	....	....
45	...	...	142	...	...	62.5	59.5	59.5	61.5
50	...	139	...	139	...	....	....	....	....
60	143	138	139	136	139	62	59	59	61.5
90	140	136	138	135	137	....	59	59	61
170	141	135	137	134	133	....	58.5	58.5	60
150	...	...	...	...	...	61	....	....	....
180	...	...	...	...	...	....	....	....	59
300	...	...	...	...	122	....	58	58	58
600	...	...	...	...	...	....	....	....	....
900	...	...	...	...	...	58	....	....	....
Max. Press. at Start, p.s.i.	350	350	350	345	350	66	66	66	65

[a] Each set of tests made with the same charge of grease which was allowed to heal between periods of circulation.
[b] Tests made at 10-min. intervals.
[c] Tests made at 2-hr. intervals.

retesting. Data obtained by this method showing the amount of healing are given in Table II.

The fact that, in the work to date both penetration and apparent viscosity vary in the same regular manner with shearing time, implies that a relationship exists between penetration and apparent viscosity, provided similar temperatures and rates of shear are employed. The shearing rate for the A.S.T.M. cone as it penetrates the grease decreases rapidly, and hence any value assigned for rate of shear is a mean value for a specific range of penetration. Several types of greases tested within the penetration range 220 to 375 at 77 F. show a satisfactory correlation between A.S.T.M. penetration and apparent viscosity at a shearing rate of approximately 10 reciprocal seconds. This relationship is shown graphically in Fig. 5 for a number of different calcium and barium greases distinct from those shown in Table I. The oil content in these greases varied over only a moderate range of viscosity. It is believed that the same type of relationship exists for other greases.

The Breakdown Process:

In following the breakdown process, as described earlier, three general methods were used. Data are shown graphically in Figs. 1, 3, 6, 7, 8, and 9 for the different greases. In these figures, penetration, net power requirement, or apparent viscosity is plotted logarithmically against time and a linear relationship is obtained. As illustrated in Fig. 9, greases were subjected to various and extended periods of working without apparently changing this relationship.

In Fig. 6, data are presented for three of the greases to show the effect of rate of shear upon the breakdown. This figure indicates that changing the rate of shear does not greatly alter the rate of breakdown. However, as is also shown by Fig. 6, the total or over-all amount of breakdown is greater with increased shearing rate.

The data presented in Fig. 7 show that the test temperature must be carefully controlled or an erroneous interpretation of the data may result as a consequence of assigning consistency changes, which are due to temperature variations, to thixotropic effects. The values can be corrected for changes caused by temperature, and these corrected values will then fall in line with values obtained under isothermal conditions.

In Fig. 8, data are presented on sodium, lithium, and barium greases to show the effect of temperature upon the breakdown process. In some instances there appears to be an effect of temperature upon the rate of breakdown within the range 77 to 150 F. In such cases raising the temperature increased the rate of breakdown.

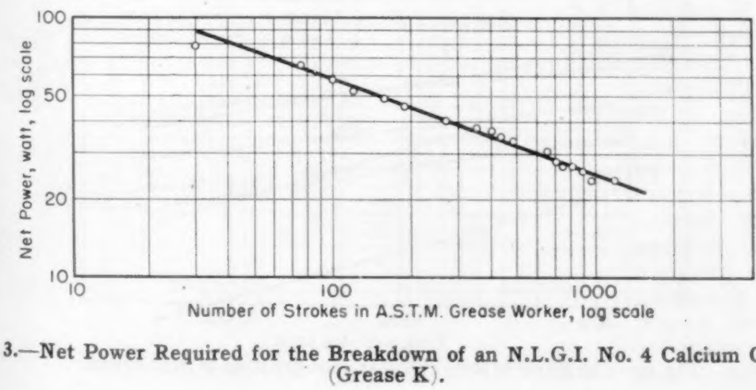

Fig. 3.—Net Power Required for the Breakdown of an N.L.G.I. No. 4 Calcium Grease (Grease K).

Reversibility:

According to the original definition of thixotropy for greases, systems must exhibit a reversible pattern in respect to consistency. The degree of reversibility has been observed in the present work to vary widely for different greases of the same types, for example, sodium, barium, etc. This is evidenced by the data in Table II and Fig. 9 for certain barium greases. In the case of other barium greases, essentially no recovery took place after extensive working, and the same behavior was noted in the case of several different sodium base greases. Probably some calcium, aluminum, and lithium greases will behave similarly depending upon their particular composition or structure. It is evident that the structure, the extent of milling, and doubtless the temperature, exercise an important influence upon the degree of reversibility, and the type of grease may well be a relatively minor factor.

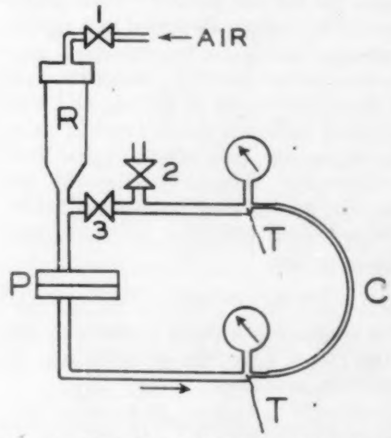

Fig. 4.—Sketch of Capillary Circulating Apparatus.

Data are presented in Fig. 9 showing the effect of extended pre-working and healing upon the breakdown process. The results are very interesting in that, for the particular grease studied, the grease rehealed to a considerable degree upon standing overnight, and the recovered structure was broken down at approximately the same rate as was that of the original grease. Not all greases, even of one type, exhibit this behavior, some recovering very little or none of their structure over a similar healing period. A study of a number of different types of greases by this method would doubtless offer some interesting comparisons in respect to their behavior in practical use.

General Discussion

From the data presented in this

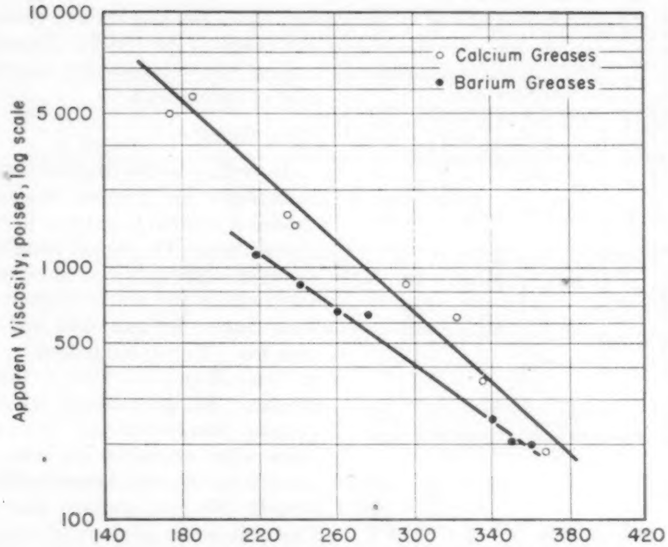

Fig. 5.—Correlation of the A.S.T.M. Worked Penetration with Apparent Viscosity at 10.8 Sec.$^{-1}$ for Barium and Calcium Greases.

paper, it appears that most, if not all, lubricating oil greases, upon being subjected to mechanical working, break down in a regular manner. Likewise, when the worked greases remain undisturbed in storage, they heal in a regular manner. As is to be expected, such factors as composition, structure, rate of shear, the extent of milling, and temperature influence the changes in varying degree, and their effects appear to be predictable. The regularity of the above behavior may be represented by the following equation for any given rate of shear:

$$\log \eta_\alpha = m \log t + \log b \quad \text{......(1)}$$

The constant b is equal to the viscosity when $t = 1$, hence the equation may be rewritten as follows:

$$\eta^\alpha = ct^m \quad \text{.......... (2)}$$

where c is the viscosity when $t = 1$. By determining the values of the slope m for the breakdown and healing processes on a specific grease under defined conditions and properly relating these values, some index of the thixotropy of the grease can be obtained. It is not believed possible, however, to develop a single or simple numerical value which will represent the thixotropy of a grease under all conditions.

In many rheological studies, the thixotropic effect is not taken into account. However, it is of significance and it must be considered, particularly in the case of grease, since Eq. 2 shows that apparent viscosity varies with time of shearing or healing. Equation 2 also indicates that a steady state need not be expected. Other workers, in attempts to reach a steady state for viscosity or shear stress, have experienced difficulty because of the time interval required or because their means of measurement did not permit sufficiently accurate determinations. In those cases where reported data (**6, 7, 8, 9, 10**) have been replotted logarithmically, linear relationships have been obtained in conformance with Eq. 2. When thixotropic effects are taken into account in the calculation of apparent viscosities the errors observed in other studies can be largely, if not entirely, eliminated. This has been done in the case of lubricating greases using capillaries for measuring apparent viscosities (**11**).

The considerations in the above paragraph ultimately raise for discussion the concept of yield point. A preference to establish a relationship between viscosity and yield point, rather than between viscosity and penetration, is expressed by other workers. However, the data obtained in the present work show that the apparent viscosity and penetration are related provided corresponding conditions of shear rate and temperature are observed. After a general review of the literature on the subject, particularly with reference to grease, the authors are impressed with the tenuousness of the evidence supporting the concept of yield point. There is a vagueness as to the method of its precise determination, and therefore its accuracy, and in some instances experimentally determined flow data are presented which are lower than the established yield value, that is, the point below which no flow is stated to take place. Such cases would seem to constitute a contradiction in terms. In other instances, the apparent contradiction or discrepancy is explained by changes in type of flow. Other workers in the same broad field have experienced similar confusion and have presented data showing that the yield points, if they exist are definitely below the values computed in the more conventional manner (**6, 7, 8, 9, 10, 12**). It has been assumed that a change in the type of flow or of structure occurs at the yield point (**2**) because a break may appear to occur when the data are plotted on a linear scale. However, in the case of greases, at least, other data show that such an assumption is not tenable, particularly since the data replotted logarithmically give straight lines. Flow rates have been measured for greases at rates of shear as low as 0.001 reciprocal sec., which represented roughly a flow rate of one g. of grease per 24 hr. It would appear, therefore, that yield points for greases, if they exist at all, must be exceedingly low, and it is not clear to the authors how it can be demonstrated on any irrefutable basis whether such critical values exist. When both the shearing stress and corresponding flow rate are so low, the latter can be observed only if the means of measurement are sufficiently accurate or if a sufficient time interval is allowed.

Practical Significance

As mentioned earlier, a knowledge of the thixotropic characteristics of a grease is interesting from the viewpoint of practical applications. For example, it is sometimes desired to estimate the

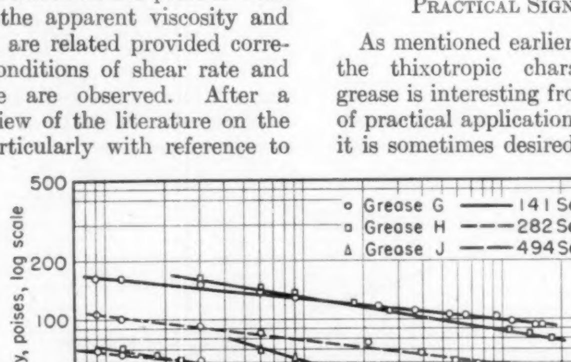

Fig. 6.—The Effect of Rate of Shear upon the Rate of Breakdown.

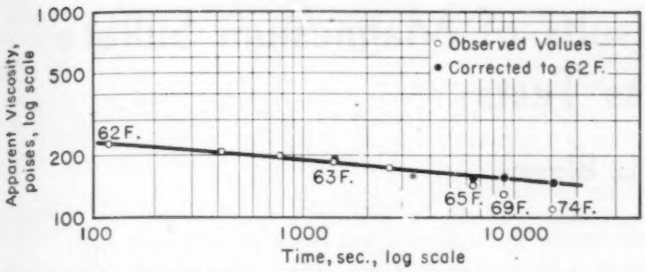

Fig. 7.—Correction of Apparent Viscosity for Temperature Rise during Breakdown Process (Grease G).

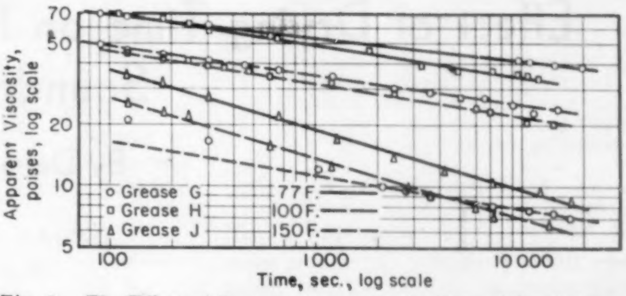

Fig. 8.—The Effect of Temperature upon the Rate of Breakdown.

extent to which greases will harden in storage. In fact, certain government specifications already embrace this particular feature in regard to penetrations on worked samples. Since the penetration of grease changes in a predictable manner with time of storage, it is a simple matter to extrapolate the curve for the linear relationship over the desired time interval and read the penetration. In the case of a number of greases examined in this manner, the data obtained by extrapolation have been reasonably consistent with observed values. Previously, no known basis existed for predicting the extent to which greases would harden in storage. How broadly this relationship applies to greases in general will be indicated after a large number of highly diversified greases have been tested. The above relationship also makes it possible to appraise the effectiveness of a milling operation in the case of a grease that is milled and stored for a prolonged period of time.

Knowledge of the thixotropic characteristics of grease suggests the manner in which it may behave in a bearing under known conditions. Where greases break down, leakage will occur unless the grease rapidly heals or sets up as soon as the shearing action ceases, unless of course a tight bearing housing prevents such leakage. If the effective rate of shear of the bearing is known, the amount of softening can be anticipated from a previous knowledge of the thixotropic characteristics of the grease. Such information is clearly of value in selecting a satisfactory grease for a given set of operating conditions.

Knowledge of the thixotropic characteristics of a grease permits prediction of its behavior in a dispensing system, whether the system be of the type used in service stations or that employed for centralized lubrication. Greases which heal markedly in storage after being packaged, or greases which break down rapidly upon being worked and heal rapidly when working stops, are apt to lead to difficulties in pumping through dispensing lines or to actual "freezing" of the system. This latter might occur where the unit was out of operation for an extended period. In the case of bearings, the same behavior would result in high starting torques. Consequently, the selection of the best lubricant for a particular application is a matter in which a knowledge of the thixotropic behavior of the grease is definitely helpful.

Conclusion

It is to be recognized that the subject of the thixotropic behavior of greases is a highly complicated one. In view of this complexity, it is possible that, as additional greases are tested in wide variety and under all conditions, some modification of the conclusions reached in this preliminary study may be required. Further work is being performed along those lines.

From the information presented in this report, it is evident that proper cognizance of thixotropy is a factor that should enter into any research program leading to the adoption of a particular grease formulation. Most grease technologists in the past have used some empirical means to make such a selection, but it is believed that the results of the present work, and any subsequent extension of the work, will suggest a more comprehensive and accurate basis for the purpose.

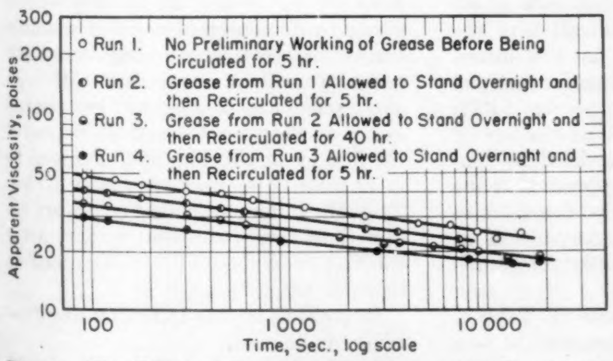

Fig. 9.—The Effect of Repeated Working at 100 F. and 494 Sec.$^{-1}$ upon the Rate of Breakdown.

Nomenclature

c = apparent viscosity when t = 1, in poises,
L = length of capillary in centimeters,
m = slope of line when log η_α is plotted against log t,
P = pressure in dynes per square centimeter,
Q = rate of flow in cubic centimeters per second,
R = radius of capillary in centimeters,
S = rate of shear, sec.$^{-1}$,
t = time in seconds, and
η_α = apparent viscosity in poises.

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Effect of Drying Time on Results of Magnesium Sulfate Soundness Tests

By Delmar L. Bloem[1]

In conducting soundness tests of concrete aggregates using magnesium or sodium sulfate, many laboratories adopt an arbitrary drying period instead of drying the samples to constant weight as provided in the A.S.T.M. Method.[2] In some cases this period has been insufficient for thorough drying with the result that different laboratories frequently get widely different losses when testing the same material.

While the effects of variables in the test procedure have been studied in considerable detail by several investigators (see appended list of references), it is believed that sufficient emphasis has not been placed on the effect of drying in the cycle. For this reason, a group of magnesium sulfate tests were conducted recently in the jointly supported laboratory of the National Sand and Gravel Association and the National Ready Mixed Concrete Association at the University of Maryland to determine the necessity for drying soundness test samples to constant weight. Although limited in scope, the data appear to be of sufficient interest to justify their being reported.

Two groups of tests were made on the same sand; in one group the samples were dried to constant weight after each cycle and in the other they were dried for only $6\frac{1}{2}$ hr. The arbitrary $6\frac{1}{2}$-hr. period was chosen because it represents the practical drying time which would be used if each cycle were run within a 24-hr. period, a common practice in many laboratories. Each group consisted of three individual samples made up of four sizes (No. 4–8, No. 8–16, No. 16–30, No. 30–50) prepared and tested in strict accordance with Method C 88, the only variable being drying time. The containers for holding the sand were 2- by $3\frac{1}{4}$-in. cylindrical baskets made of wire mesh having an opening less than half as large as the sieve upon which the sample was originally retained.

For the group subjected to one cycle per day, the cycle consisted of $16\frac{1}{2}$ hr. in magnesium sulfate solution, $6\frac{1}{2}$ hr. in the oven at 220 to 230 F. and 1 hr. cooling prior to being replaced in the solution. The cycle for samples dried to constant weight was the same except that the drying period was extended to $30\frac{1}{2}$ hr. The temperature of the $MgSO_4$ solution was maintained between 70 and 72 F. with an average specific gravity of 1.297 for both groups of tests.

TABLE I.—SUMMARY OF $MGSO_4$ SOUNDNESS TESTS OF SAND (LOT 1957).

Particle Size or Item	Sieve Analysis, Individual per cents	Per Cent Loss on First Sieve[a]				Per Cent Loss on Second Sieve[b]			
		Test 1	Test 2	Test 3	Avg.	Test 1	Test 2	Test 3	Avg.
Group I—Samples Dried 6½ hr. at 220 to 230 F.									
+No. 4	3.3	(16.0)[c]	(15.7)	(19.1)	(16.9)	(11.6)	(11.7)	(15.2)	(12.8)
No. 4–8	11.6	16.0	15.7	19.1	16.9	11.6	11.7	15.2	12.8
No. 8–16	6.9	10.5	11.9	11.4	11.3	7.0	8.0	7.6	7.5
No. 16–30	16.5	5.8	5.1	4.7	5.2	3.1	2.7	2.3	2.7
No. 30–50	41.1	2.4	3.1	2.7	2.7	1.3	1.4	1.0	1.2
No. 50–100	14.6	....	....	....	....	....	....	....	....
−No. 100	6.0	....	....	....	....	....	....	....	....
Weighted per cent loss	...	5.1	5.3	5.5	5.3	3.2	3.3	3.6	3.4
Group II—Samples Dried 30½ hr. at 220 to 230 F. (to Constant Weight)									
+No. 4	3.3	(22.3)[c]	(20.0)	(22.5)	(21.6)	(18.3)	(15.9)	(18.0)	(17.4)
No. 4–8	11.6	22.3	20.0	22.5	21.6	18.3	15.9	18.0	17.4
No. 8–16	6.9	24.5	25.7	24.0	24.7	18.3	19.3	18.0	18.5
No. 16–30	16.5	17.0	16.9	13.5	15.8	10.8	10.1	8.5	9.8
No. 30–50	41.1	11.7	11.1	12.0	11.6	6.9	6.9	7.2	7.0
No. 50–100	14.6	....	....	....	....	....	....	....	....
− No. 100	6.0	....	....	....	....	....	....	....	....
Weighted per cent loss	...	12.6	12.1	12.2	12.3	8.6	8.2	8.3	8.4
Ratio: $\frac{\text{Loss for } 30^1/_2 \text{ hr. dry}}{\text{Loss for } 6^1/_2 \text{ hr. dry}}$									
No. 4–8	...	....	....	....	1.3	....	....	....	1.4
No. 8–16	...	....	....	....	2.2	....	....	....	2.5
No. 16–30	...	....	....	....	3.0	....	....	....	3.6
No. 30–50	...	....	....	....	4.3	....	....	....	5.8
Weighted average	...	....	....	....	2.3	....	....	....	2.5

[a] Sieve on which sample was originally retained.
[b] Sieve one-half size of that on which sample was originally retained.
[c] Insufficient for test; assumed same as for adjacent size, No. 4 to 8.

Test results are given in Table I. Good agreement was obtained between the individual tests within each group and there is a clear indication of the effect of drying time on the losses. The average weighted loss for samples which received one cycle per day (dried $6\frac{1}{2}$ hr.) was less than half as great as for the samples which were dried to constant weight. Thus it appears that the selection of a drying period too short to attain constant weight may result in losses which are consistently very much too low.

It is interesting to note in Table I that the differences in loss for the two conditions of test become greater as the size of material tested becomes smaller. The loss on the first sieve for the No. 4–8 size dried $30\frac{1}{2}$ hr. was only 1.3 times as great as for that dried $6\frac{1}{2}$ hr. while for the No. 30–50 material the ratio was 4.3. Therefore, it appears that coarser materials such as gravel or the larger sizes of sand require a shorter drying period than the finer sizes of sand. This seems logical since the larger sizes have much less surface area to be dried and larger voids to permit the circulation of air.

Table II, showing losses in weight from $6\frac{1}{2}$ to 24 and 24 to $30\frac{1}{2}$ hr., is given to demonstrate another possible source of error in running soundness tests. It will be noted that, although there was a loss in weight of less than 6 per cent between $6\frac{1}{2}$ and 24 hr. after the first cycle, this loss had increased to more than 12 per cent after later cycles. Thus the minimum period of drying required to attain constant weight after the first cycle should not be assumed to be sufficient for later cycles.

In conclusion, the following observations can be made:

1. With the type of container used in these tests it was not possible to dry

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[2] Tentative Method of Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (C 88–46 T), 1946 Book of A.S.T.M. Standards, Part II, p. 1400.

magnesium sulfate soundness test samples of sand to constant weight in less than about 30 hr.

TABLE II.—DRYING DATA—$MGSO_4$ SOUNDNESS TESTS OF SAND. SAMPLES DRIED $30\frac{1}{2}$ HR. AT 220 TO 230 F.

Cycle	Loss in Weight of 12 Samples (1200 g.) of Sand[a]			
	Between $6\frac{1}{2}$ and 24 hr. drying		Between 24 and $30\frac{1}{2}$ hr. drying	
	g.	per cent	g.	per cent
1...	69	5.8	3.5	0.3
2...	121	10.1	6.5	0.5
3...	150	12.5	2.0	0.2
4...	[b]	[b]	0.0	0.0
5...	146	12.2	13.5	1.1

[a] Entire set of 3 samples weighed together. Individual baskets not weighed.
[b] Not weighed at $6\frac{1}{2}$ hr.

2. Samples tested at the rate of one cycle per day had losses less than one half as great as those which were dried to constant weight after each cycle.

3. The smaller the size of aggregate tested, the greater the drying time required to insure uniform results and the greater the error introduced by using an insufficient drying period.

4. It is not sufficient to determine the time required to dry to constant weight after the first cycle and use that drying period for subsequent cycles since drying becomes more difficult as the test progresses due to salt deposits building up on the aggregate particles and in the voids.

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Load Concentration in Corrugated Paper

By J. H. Toulouse[1] and P. J. Barcus[1]

IN RECENT years, attention has centered on the protection afforded glass containers and other products by corrugated fiber shipping containers and partitions. This report gives results of a study of such protection and the possibility of an objective approach to specification. It is a part of a program of research leading to recommendations for shipping container rules and specifications.

In general, the previous method of approach has been one of experience and compromise. Very largely it has been a matter of opinion, in which men of experience could easily disagree. In an engineering, objective approach, differences of opinion could be narrowed down and a broad basis of agreement established.

Other researches, using the Inclined Impact Tester,[2] have shown, where glass containers are concerned, that protection was largely a matter of the makeup of the partitions or sheets separating the bottles *within* the same shipping container. This is shown by the fact that the breakage usually occurred in a position in the shipping container away from the point of application of external force, through crushing of the partition, which allowed bottle-to-bottle contact through the crushed partition walls. Therefore, we are less concerned with the outer layer of protection and more concerned with the crush resistance of the partition material. The following is the reasoning back of the present work:

1. In order to enable uncushioned contact, each bottle is considered to embed itself into the partition stock until it reached the halfway point of the partition, where it meets another bottle moving toward it and also penetrating halfway.

2. The halfway point is one half of the total thickness, less the combined caliper of the facings and corrugating material.

3. When the halfway point is reached, there is a definite area of the bottle in contact with the partition. This area is roughly the chord subtended by the arc of the bottle in contact times the length in contact. As such, it differs with the bottle, being relatively longer with larger round bottles, and of various areas with other than round, cylindrical bottles. It also differs with the thickness of the board, as with *A*, *B*, or *C* flutes.

4. The force which embeds the bottle into the corrugated media is determined by the weight of the bottle and its contents. In general, since most of the weight is in the contents, which may differ according to the specific gravity of the product contained, it is essential to know the weight of the entire package.

5. From this, it is now possible to express the conditions of packaging in terms of pounds of force per square inch of contact area. This may readily be determined for any filled glass container, either by calculation or experiment.

6. Theoretically, the pounds per square inch will range from small values for small capacity bottles to large values for large capacity bottles.

7. The resulting test values on the inclined impact testing machine should range from those approaching infinity, as the load concentration becomes smaller and smaller, to approaching zero as the load concentration becomes larger and larger.

8. Theoretically, the curve expressing such a condition will be a hyperbola.

As a result of some previous work, a number of tests were available in which we had determined the weight of the filled glass package, the area of contact, the load concentration, and the average (of ten) inclined impact test for both single wall and multiple wall partitions of the same paper stocks. The single wall partitions were of *A*, *B*, and *C*

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[2] Standard Method of Incline Impact Test for Shipping Containers (D 880–47), 1947 Supplement to Book of A.S.T.M. Standards, Part III-B, p. 23.

flutes, with the first two of chip facings, and the latter of both chip and 200-lb. test facings. The multiple wall partitions were of both *A-B* flute double-wall corrugated board with chip facings, and two thicknesses of *C* flute single-wall corrugated board with chip facings.

NOTE.—Throughout our work it has been shown that the facing has a minor role in the protection given. This is shown by the fact that the hyperbolas for single walls are almost identical. For brevity in this report they are combined, but anyone interested can develop the separate curves from the data given. We do not go so far as to state that there is no difference between flute styles—only that the results are so closely together that no firm distinction can be made.

The formula for the hyperbola is given as $XY^n = K$ where X is the load concentration in pounds per square inch, Y is the footfalls by the progressive method for the inclined impact tester, and n and K are constants. The constants are calculated from the data by the method of least squares, and the hyperbolas constructed accordingly.

The curves show a marked difference between single and double walls, and enable choice of wall to be made on the basis of a minimum average inclined impact test value. Agreement upon the minimum value to be used enables direct specification to be made.

In order to use the method of least squares it is necessary to change the form of the formula of the hyperbola into one which allows a straight line graph. This is easily done by taking the logarithms of the elements of the formula, as follows:

There can be two formulas for the curve depending upon which variable is taken as, being dependent upon the other (the n is not necessarily the same value):

$$XY^n = K \quad (X \text{ dependent on } Y)$$
$$X^nY = K \quad (Y \text{ dependent on } X)$$

Taking the logarithms:

$$\log X + n \log Y = \log K$$
$$n \log X + \log Y = \log K$$

It will be easier to make temporary substitutions for the logarithms; as $\log X = z$, $\log Y = u$, $\log K = C$. The expressions then become:

$$z + nu = C$$
$$nz + u = C$$

In applying the method of least squares, the summations are taken as follows:

1. For X dependent on Y:

$$\Sigma z + n\Sigma u = NC$$
$$\Sigma uz + n\Sigma u^2 = C\Sigma u$$

2. For Y dependent on X:

$$n\Sigma z + \Sigma u = NC$$
$$n\Sigma u^2 + \Sigma uz = C\Sigma z$$

TABLE I.—DEVELOPMENT OF SUMMATIONS FOR SINGLE WALL BOARD

Wall	X	Y	z	u	uz	z^2	u^2
A	0.40	42	−0.3979	1.6232	−0.6459	0.1583	2.6348
	0.95	17	−0.0223	1.2304	−0.0274	0.0005	1.5139
	1.43	9	+0.1553	0.9542	+0.1482	0.0241	0.9105
	0.43	37	−0.3665	1.5682	−0.5747	0.1343	2.4593
	0.36	47	−0.4437	1.6721	−0.7419	0.1969	2.7959
	0.56	26	−0.2518	1.4149	−0.3563	0.0634	2.0019
B	0.71	26	−0.1487	1.4150	−0.2104	0.0221	2.0022
	0.48	34	−0.3098	1.5315	−0.4745	0.0960	2.3455
	0.65	34	−0.1871	1.5315	−0.2865	0.0350	2.3455
	0.60	27	−0.2219	1.4314	−0.3176	0.0492	2.0489
	0.48	32	−0.3098	1.5052	−0.4663	0.0960	2.2656
C	0.45	33	−0.3468	1.5185	−0.5266	0.1203	2.3058
	0.57	34	−0.2441	1.5315	−0.3738	0.0596	2.3455
	0.41	60	−0.3872	1.7782	−0.6885	0.1499	3.1620
	0.52	27	−0.2840	1.4314	−0.4065	0.0807	2.0489
	0.63	24	−0.2007	1.3802	−0.2770	0.0403	1.9050
C (test)	0.45	33	−0.3468	1.5185	−0.5266	0.1203	2.3058
	0.48	35	−0.3188	1.5441	−0.4922	0.1016	2.3842
	0.57	49	−0.2441	1.6902	−0.4126	0.0596	2.8568
	0.54	33	−0.2676	1.5185	−0.4064	0.0716	2.3058
	0.41	69	−0.3872	1.8388	−0.7120	0.1499	3.3819
	0.39	40	−0.4089	1.6021	−0.6551	0.1672	2.5667
	0.52	42	−0.2840	1.6232	−0.4610	0.0807	2.6348
	0.48	50	−0.3188	1.6990	−0.5416	0.1016	2.8866
	0.63	34	−0.2007	1.5315	−0.3074	0.0403	2.3455
Σ's	..	..	−6.7439	38.0833	−10.7406	2.2194	58.7593
N = 25							
1/N	..	..	−0.2698	1.5233	−0.4296	0.08878	2.3504

The summations are developed in Tables I and II for single and double walls, respectively. N in each case is the number of separate determinations in each group. The necessary values are inserted in the formulas above, and the equations solved for n and C.

1. For single walls, A, B, and C flutes:

Because the same curve, within the limitations of the data obtainable, closely approximated the results from all flute styles with a high degree of correlation, the curve for single wall (double faced) board is here developed as a composite. The first step was to make the summations as in Table I.

Next, the correlation coefficient was calculated from the summations:

$$\sigma u = (2.3504 - 1.5233^2)^{\frac{1}{2}}$$
$$= 0.173$$
$$\sigma z = (0.088776 - 0.2698^2)^{\frac{1}{2}}$$
$$= 0.12654$$
$$r = \frac{-uz - (-u'z')}{\sigma z \, \sigma u}$$
$$= \frac{-0.42962 + 0.41092}{0.02189}$$
$$= -0.854$$

A correlation coefficient of 0.854 is considered very good correlation.

(*a*) Calculation of curve, Y dependent upon X.

Substituting in the formulas already given, from values in Table I:

$$-6.7439n + 38.0833 = 25C$$
$$2.2194n - 10.7406 = -6.7439C$$

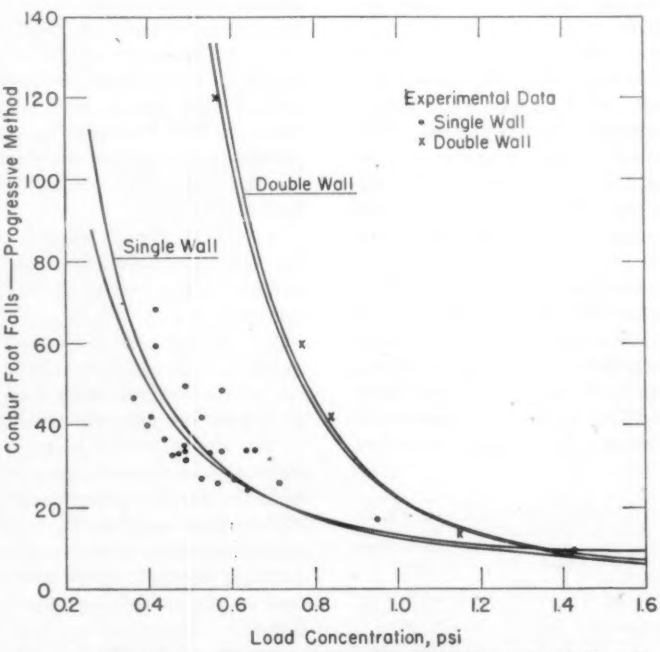

Fig. 1.—Curves for Single and Double Wall Corrugated Board. Conbur Test as Load Concentration.

TABLE II.—DEVELOPMENT OF SUMMATIONS FOR DOUBLE WALL BOARD.

X	Y	z	u	uz	z^2	u^2
0.53	156	−0.2757	2.1931	−0.6046	0.07601	4.8097
0.77	60	−0.1135	1.7782	−0.2018	0.01288	3.1620
1.15	14	+0.0607	1.1461	+0.0696	0.00368	1.3135
0.56	120	−0.2518	2.0792	−0.5235	0.06340	4.3231
0.84	42	−0.0757	1.6232	−0.1229	0.00573	2.6348
Σ's	...	−0.6560	8.8198	−1.3832	0.16170	16.2431
N = 5						
1/N	...	−0.1312	1.7639	−0.2766	0.03234	3.2486

Solving for C:

$$\begin{aligned} -14.9674n + 84.5221 &= 55.4850C \\ +14.9574n - 72.4335 &= -45.4802C \\ 12.0886 &= 10.0048C \\ 1.2083 &= C \end{aligned}$$

Solving for n:

$$\begin{aligned} -6.7439n + 38.0833 &= 30.2070 \\ -6.7439n &= -7.8763 \\ n &= 1.1679 \end{aligned}$$

Therefore, the curve can be expressed as:

$$1.17z + u = 1.21$$

the values of points for which are calculated as:

$$u = 1.21 - 1.17z$$

To set up points for the curve, we calculate as follows:

z	u	X	Y
+0.20	0.9760	1.585	9.5
+0.15	1.0345	1.413	10.8
+0.10	1.0930	1.259	12.4
+0.05	1.1515	1.123	13.3
0.00	1.2100	1.000	14.2
−0.05	1.2685	0.891	18.5
−0.10	1.3270	0.795	21.2
−0.15	1.3855	0.708	24.3
−0.20	1.4440	0.631	27.8
−0.25	1.5025	0.562	31.8
−0.30	1.5610	0.502	36.4
−0.35	1.6195	0.447	41.6
−0.40	1.6780	0.398	47.6
−0.45	1.7365	0.355	54.5
−0.50	1.7950	0.316	62.4
−0.55	1.8535	0.282	71.3
−0.60	1.9120	0.251	81.7

(*b*) Calculation for curve, X dependent on Y.

Substituting in formulas already given, from values in Table I:

$$\begin{aligned} -6.7439 + 38.0833n &= 25C \\ -10.7406 + 58.7593n &= 38.0833C \end{aligned}$$

Solving for C:

$$\begin{aligned} -396.2668 + 2237.7481n &= 1468.9825C \\ -409.0375 + 2237.7481n &= 1450.3377C \\ 12.7707 &= 18.6448C \\ 0.685 &= C \end{aligned}$$

Solving for n:

$$\begin{aligned} -6.7439 + 38.0833n &= 17.1237 \\ n &= 0.627 \end{aligned}$$

The formula for the curve becomes:

$$z = 0.627u + 0.685$$

which gives the following calculated values:

z	u	X	Y
+0.20	0.7735	1.585	5.9
+0.15	0.8532	1.413	7.1
+0.10	0.9330	1.259	8.6
+0.05	1.0129	1.123	10.3
0.00	1.0925	1.000	12.4
−0.05	1.1723	0.891	14.9
−0.10	1.2520	0.795	17.9
−0.15	1.3318	0.708	21.5
−0.20	1.4115	0.631	25.8
−0.25	1.4913	0.562	31.0
−0.30	1.5710	0.502	37.2
−0.35	1.6508	0.447	44.8
−0.40	1.7305	0.398	53.8
−0.45	1.8103	0.355	64.6
−0.50	1.8900	0.316	77.6
−0.55	1.9698	0.282	93.3
−0.60	2.0494	0.251	112.0

2. *For multiple walls:*

The first step is the development of summations as in Table II.

The coefficient of correlation is calculated as follows:

$$\begin{aligned} \sigma z &= (0.03234 - 0.1312^2)^{1/2} \\ &= (0.01513)^{1/2} \\ &= 0.123 \\ \sigma u &= (3.2486 - 1.7639^2)^{1/2} \\ &= (3.2486 - 3.1113)^{1/2} \\ &= 0.1373^{1/2} \\ &= 0.371 \\ r &= \frac{-0.27664 - (-0.23143)}{\sigma z \ \sigma u} \\ &= \frac{-0.04521}{0.04563} \\ &= -0.99 \end{aligned}$$

(*a*) Calculation of curve, Y dependent on X.

$$\begin{aligned} -0.6560n + 8.8198 &= 5C \\ 0.1617n - 1.3832 &= -0.6560C \end{aligned}$$

Solving for C:

$$\begin{aligned} -1.06075n + 1.4262 &= 0.8085C \\ +1.06075n - 0.9074 &= -0.4303C \\ 0.5188 &= 0.3782C \\ 1.372 &= C \end{aligned}$$

Solving for n:

$$\begin{aligned} -0.656n + 8.8198 &= 6.860 \\ -0.656n &= 1.9598 \\ n &= 2.988 \\ 2.988z + u &= 1.372 \end{aligned}$$

Calculating the table for the curve:

z	u	X	Y
+0.20	0.7744	1.585	5.94
+0.15	0.9238	1.413	8.39
+0.10	1.0732	1.259	11.8
+0.05	1.2226	1.123	16.7
0.00	1.3720	1.000	23.6
−0.05	1.5214	0.891	33.2
−0.10	1.6708	0.795	46.9
−0.15	1.8202	0.708	66.1
−0.20	1.9696	0.631	93.3
−0.25	2.1190	0.562	131.5
−0.30	2.2684	0.502	185.6

(*b*) Calculation of curve, X dependent on Y.

$$\begin{aligned} -0.656 + 8.8198n &= 5C \\ -1.3832 + 16.2431n &= 8.8198C \end{aligned}$$

Solving for C:

$$\begin{aligned} -10.65547 + 143.2609n &= 81.2155C \\ -12.19955 + 143.2609n &= 77.7889C \\ 1.54408 &= 3.4266C \\ 0.451 &= C \end{aligned}$$

Solving for n:

$$\begin{aligned} -0.656 + 8.8198n &= 2.255 \\ 8.8198n &= 2.911 \\ n &= 0.3298 \\ z + 0.33u &= 0.451 \end{aligned}$$

Calculation of points for the curve:

z	u	X	Y
+0.20	0.7607	1.585	5.8
+0.15	0.9122	1.413	8.2
+0.10	1.0637	1.259	11.6
+0.05	1.2152	1.123	16.4
0.00	1.3667	1.000	23.2
−0.05	1.5182	0.891	33.0
−0.10	1.6697	0.795	46.7
−0.15	1.8212	0.708	66.3
−0.20	1.9727	0.631	93.9
−0.25	2.1242	0.562	133.3
−0.30	2.2757	0.502	189.7

The curves and test values are shown in Fig. 1.

Summary

1. It is shown that experimental values follow the curve of a hyperbola, when concentration of load is compared with conbur foot falls.

2. The curve for single wall corrugated board was distinctly different from the curve for double wall or double thickness.

3. This makes it possible to specify the kind of interior packing, based upon measurement of load concentration (bottle and content weight *versus* contact area), which places specification of interior packing on an objective basis. Further work is needed to outline the field of application more completely.

Metals and Plastics[1]

By Robert G. Chollar[2]

It is extremely dangerous to generalize on the implications behind any two major fields of materials. Errors of omission have a habit of becoming important at times, although it might not be too unreasonable to consider the lack of judicious comparison of metals and plastics and their properties as a major error of omission in recent engineering literature.

In analyzing the activity of these two materials it would be well first to observe their importance in terms of volume output. Comparison of production figures of 1939 and 1944 is given in Table I.

TABLE I.—ANNUAL PRODUCTION OF CERTAIN INDUSTRIAL MATERIALS IN U. S., 1939–1944 IN MILLIONS OF POUNDS. (American Iron and Steel Inst., American Bureau of Metal Statistics, and the U. S. Tariff Commission.)

Material	1939	1944
Steel	105 597	179 283
Copper	2 279	3 691
Aluminum	427	2 179
Plastics	255	907
Magnesium	7	367
Percentage of Plastics, aluminum, and magnesium to steel	0.7	1.9

Production of plastic materials by 1944 figures approximated 24.6 per cent that of copper, 41.6 per cent that of aluminum, and greatly exceeded that of magnesium. The plastics output was actually less than one per cent of the total of steel. It is apparent from the percentage comparison of the total output of aluminum, magnesium, and plastics, that they made a greater contribution, as compared to steel, than they did in 1939.

Relative importance according to utilization may be observed in Table II. For evaluation purposes it is considered that, empirically, plastics may be said to embrace all those synthetic materials which may be molded, extruded, cast, or used as a coating, or in the form of adhesives for laminated materials.

TABLE II.—RELATIVE USES OF PLASTICS. ("An Engineering Interpretation of the Economic and Financial Aspects of American Industry," George S. Armstrong and Co., Vol. VII, 1946.)

Type of Usage	Percentage of Total
Protective coatings	36
Molding	29
Laminating	12
Adhesives	9
Miscellaneous	14
Total	100

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at the Symposium on Plastics at a meeting of Committee D-20 on Plastics held in Cincinnati, Ohio, March 4 and 5, 1947.

[2] Director of Research, The National Cash Register Co., Dayton, Ohio.

It is obvious from this that the majority of these synthetic materials are still used in the field of coating for protective purposes.

The procuring of quantitative information with respect to the end uses of plastic materials is quite difficult. A catalog of all their applications would be endless. Generally speaking, and in order of relative magnitude of consumption, these uses might be classified as shown in Table III.

TABLE III.—CIVILIAN USES OF PLASTICS.

	Percentage Consumption
Electrical and affiliated products	43
Packaging	20
Textiles	14
Construction and railroads	10
Automotive	4
Housewares and hardware	2
Novelties and toys	2
Business machines	1
Miscellaneous	4
Total	100

The manufacture of electrical equipment is one of the largest consumers of plastic materials. Largely in laminated form, where their insulating values or high dielectric strength and low loss qualities are significant, the plastics used in electrical equipment are estimated to comprise nearly one half of the total value of the laminate field. In this, a major end use of plastics, a property inherent to organic material permits no competition from the metals field.

Packaging uses plastic materials of many kinds in a variety of ways—in coated paper, in closures, in transparent forms for envelopes and food wrapping, and in containers. Where transparency and weight are factors plastics suffer no important competition from the metals in this field.

One of the important uses of plastic materials is in the treatment of textile fibers, yarn, and fabrics. Plastic materials are used to impregnate or saturate such textile materials as well as to size and coat them, thus not only embracing certain of the inherent or natural properties of these textile materials but also imparting properties or qualities not inherent originally in them. Here again, due to their properties, plastic materials lend themselves to applications were there is no question of competition with metals.

Plastics as Engineering Materials

In the construction, railroad, and automotive industries, which utilized only about 14 per cent of the total amount of plastics consumed, materials are used chiefly for their engineering properties, and when we recognize that the bulk of metal consumed is in these industries, the minor role that plastics have played so far as engineering materials becomes apparent.

What are engineering materials and why have plastics played a poor second to metals in their ranks? The term "engineering materials" usually denotes those that are suitable for use in the construction of stress-bearing structures. It is apparent from the utilization data shown that the general use of plastics has been largely limited to engineering applications which require materials to be only self-supporting rather than to carry primary stresses. Part of this limitation has been due to the basic nature of plastic materials and part due to a lack of knowledge of their fundamental properties.

Properties

For the purpose of discussion, a table of properties (Table IV) has been developed which includes materials used in large volumes in both the plastic and metal fields. Each material quite obviously represents hundreds of specific types within its general classification. The properties listed must not be construed as anything but an average developed for the sake of comparison in this discussion. Specific formulations within any of the listed materials may fall well away from the average in any one or several of the properties mentioned.

Materials selected for comparison cover the following classifications:

1. Molded "phenolics" encompass both general-purpose and impact-type materials.
2. Laminated "phenolics" cover the paper and fabric base materials.
3. Data were acquired on typical low-pressure mold materials in the case of the glass laminates.
4. Data for "ureas" apply to the cellulose-filled general-purpose types.
5. Injection-molded materials as covered by the three A.S.T.M. listed types are considered in the case of vinyl chloride-acetate.
6. Methyl methacrylates include both compression and injection materials of the general-purpose and heat-resistant grades.
7. The data for polystyrene cover the range listed by the Plastics Materials Manufacturers Association and found in the "A.S.T.M. Standards on Plastics."

TABLE IV.—COMPARISON OF PLASTIC AND METAL PROPERTIES.

	Specific Gravity	Comparative Cost	Comparative Hardness	Comparative Shock Resistance	Tensile Strength, psi.	Thermal Expansion, 10^{-5} per deg. Cent.	Thermal Conductivity 10^{-4} Cal. per sec. per sq. cm. per deg. Cent. per cm.	Heat Distortion at 264 psi., deg. Fahr.	Dielectric Strength, volts per mil.	Modulus of Elasticity, psi. $\times 10^{-5}$	Damping Capacity	Deformation Under Load of 4000 psi. at 122 F., 24 hr., per cent	Water Absorption, 24 hr., per cent	Color Possibilities
Phenolics (molded)	1.4	5–10	45	1–33	5 000 12 000	3.0	4–7	275	250–400	7–15	High	0.4	0.4–2	Limited
Phenolics (laminated)	1.4	18–24	33	3–48	5 000 15 000	1.5	5–8	>325	200–700	7–30	High	Low	1–4	Limited
Glass laminates	1.7	33–40	40	25–130	40 000 50 000	0.6	3–5	>320	450–650	20–25	High	Low	0.3–0.6	Limited
Ureas	1.5	10–14	48	1.0	5 000 13 000	3.0	7.0	275	300–500	12–15	High	0.55	1–3	Unlimited
Vinyl chloride-acetates	1.4	16–23	18	1–2	6 000 10 000	6.9	4.0	130	400	4	High	1–20[a]	0.1	Unlimited
Methyl methacrylates	1.2	28	26	1–2	6 000 10 000	8.0	4–6	140–200	500	3–6	High	2–12	0.4	Unlimited
Polystyrene	1.1	9–14	20	1–2	5 000 9 000	7.0	2–3	160–180	500–700	2–6	High	0.5–5	0–0.05	Unlimited
Polyamide	1.1	53	26	4–6	7 000 10 000	10.0	6.0	170	375	3–4	High	4.0	1.5	Unlimited
Cellulosics	1.2	14–24	10	2–38	2 000 10 000	12.0	4–8	110–215	250–600	0.5–4	High	1–65[a]	1–6	Unlimited
Steel	7.8	1–17	120–800	17–300	40 000 250 000	1.26	1150	1000[b]	Conductor	280	Low	Nil	0	External applications
Aluminum	2.7	5–8	30–115	8–65	13 000 76 000	2.40	4800	460[b]	Conductor	103	...	Nil	0	External applications
Magnesium	1.7	7	40–95	3–30	20 000 48 000	1.43	2500	450[b]	Conductor	65	Intermediate	Nil	0	External applications
Zinc	7.1	4–5	70–100	105–140	30 000 52 000	2.63	2700	...	Conductor	124	...	Nil	0	External applications

[a] Extreme deformation characteristics of material required test method revision to 1600 psi. load for 6 hrs.
[b] Above these temperatures physical properties drop rapidly.

8. The FM-1 nylon material is representative of the nylon data listed.

9. "Cellulosics" include the acetate acetate butyrate, and ethyl cellulose and the data embrace compression and injection materials for the S-3 and H-4 grades.

10. The steel properties cover those from the sheet and strip materials to the common alloy steels. Special property tool steels, etc., have been excluded.

11. "Aluminum" embodies a range from commercially pure to heat-treatable aluminum alloys.

12. "Magnesium" covers the commonly used magnesium alloys.

13. "Zinc" also covers the popular zinc alloys, for, as in the case of magnesium, the pure metal has little usage in engineering application.

Specific Gravity:

Specific gravity, or low weight per unit volume, is obviously important wherever weight saving is a prime factor. It is also of great importance in dynamic applications where rotational or vibrational inertia is a key to successful performance. The properties listed show the plastics to be outstanding in this respect in comparison to steel and zinc. It is well to note, however, that both aluminum and magnesium approach the plastics in low specific gravity and both, as a result of war development in raw material capacity and processing technique, are now ready for prosecution as major light-weight engineering materials in both casting and fabrication fields.

Comparative Costs:

In the second column comparative material costs per weight are given, taking the low cost of steel as the unit and converting other costs accordingly. With the exception of one or two of the high-priced plastics and zinc in the metal field, it is surprising to note the similarity in material costs between plastics and metals when considered on a volume basis.

Hardness Properties:

Hardness properties are misleading. Because of great differences in surface hardness among some organic and metallic materials, hardness results are interpreted on entirely different scales. Conversion to a single scale for comparison as shown here evaluates the tremendous range yet to be surmounted in the organic field.

The data here were acquired at The National Cash Register laboratories by the use of the Tukon Micro-Hardness Tester, made by The Wilson Company. All data are recorded in Knoop numbers.

Although the Tukon Tester is a highly sensitive metallurgical research tool, its ability to measure hardness over a scale encompassing both the soft organic materials and the metals alike, makes it an instrument that will acquire considerable importance in both the coating and plastic fields.

Hardness is a determining factor in dynamic applications in such fields as that of business machines, where it is not uncommon to have a machine with 18,000 small moving parts whose surfaces are protected from wear by layers of metal varying in hardness from the bulk of the part. This property of localized hardness in metals procedured by heat treatment is one which is yet to be met in organic materials and is of utmost importance to applications involving many interrelated small moving parts operating under variable stresses.

Shock Resistance:

Comparative shock or impact strengths of materials also have been misleading by virtue of different tests necessarily used in the two fields of metal and plastics engineering. Their comparison on a volume basis is shown above using the Izod impact strength—foot-pounds per inch of notch—and the figure of 0.24 for general-purpose phenolic as unity.

Tensile Strength:

Tensile strength is a property which is subject to considerable variation depending on manufacture, molding technique, degree of polymerization, amount and kind of fillers and plasticizers present, temperature, and moisture. Plastic materials develop tensile properties during formation of the molecular structure of the resin. By themselves the resins have a limited tensile strength although when reinforced (as in the

glass laminates) the range is well up toward the metal properties. On a volume basis the laminates cannot as yet compete with the stronger metals, although they fare well in contrast with some of the lighter ones shown. On a weight basis, however, pound for pound, the laminates approach even the better metals in certain applications. In the aircraft industry where weight is of utmost importance this property has been well utilized and most certainly will be expanded in application.

Thermal Expansion:

Peculiarly enough, thermal expansion is a property which is somewhat neglected in the consideration given materials by some engineers. Its importance can be quite apparent when specific applications are considered.

A business machine might be assumed to require a temperature range of 40 C. as its possible environmental condition for actual operation. It may also meet an 80-deg. gradient in shipping. A 1-ft. length of steel would vary about 0.006 in. over this range of operation while varying 0.012 in. during shipping. A cellulosic material, on the other hand, may vary $\frac{1}{16}$ and $\frac{1}{8}$ in., respectively, under these conditions. It requires little imagination to observe the care which must be taken in selection of materials for application involving only normal environmental temperature change, let alone extraneous added temperature conditions. The combination of both metals and plastics in either dynamic or static application must be carefully examined in this respect. In this characteristic, the reinforced plastics come closest to the metal for acceptance as an engineering material, and indeed even surpass them in certain instances.

Thermal Conductivity:

The tremendous differences in thermal conductivity between the metals and plastics denote little competition between them when it is important to have or not to have this property. There have been plastic bearing designs where temperature rise under load and speed have rendered the design unfit for service due to lack of conduction of heat from the source. On the other hand there are many designs where low heat conductivity of plastics has found many new applications in design such as knobs for oven doors, steam radiators, etc.

Heat Resistance:

Heat resistance or maximum safe operating temperature is a very intangible property to discuss. The properties developed for the plastics were obtained by the A.S.T.M. Heat Distortion Method.[3] Figures for the metals are those at which physical properties tend to drop rapidly. A peculiar situation exists with the polyamide types where molded nylon is form stable to within a few degrees of 500 F. but under load distorts at far lower temperatures. Although the relatively sharp melting point permits the use of this type material at higher temperatures than most injection-molded materials under service conditions requiring no stresses, the temperature limitation still exists where the material is considered for engineering application. With the exception of the polyamide types, it is obvious that the thermosetting materials can be operated at higher temperatures than the thermoplastics, while neither have the latitude possessed by the metal field. Knowledge of the service temperature range is essential in any engineering design of plastics application. Without a knowledge of this range, it is impossible to make the first decision of choice of material. It is important to realize that temperature changes affect the properties of plastic materials far more than they do the metals, and a complete picture of strength and other properties at the service temperature to be encountered must be obtained before an intelligent choice of material can be made.

Dielectric Strength:

With respect to dielectric strength, there is, of course, no competition between metals and plastics. Dielectric and other electrical low loss properties are the basis for the largest outlet for plastic materials to date.

Modulus of Elasticity:

Easily the most decisive property in the use of materials for the great bulk of structural engineering applications has been the modulus of elasticity. For design problems requiring a rigid structural member, the majority of plastics have been unsuited unless designed with reinforcing ribs. Compared to steels with a modulus of 28,000,000 psi. or aluminum of 10,000,000 psi., the range of moduli for plastic materials (200,000 to 1,500,000 psi.) seems rather inadequate. There are, of course, miscellaneous designs which require low moduli. Low modulus signifies high resiliency for the load-deformation characteristics imparted to the structural member. This resiliency has been the keynote of quiet operation of plastic gears, etc. However, modulus of elasticity remains the limiting property behind the great mass of applications of plastic materials as compared to metals.

The effect of the mode of application of stress is often significant and varies appreciably between metals and plastics. In plastics, stresses applied quickly and removed quickly in the manner of those accompanying vibrations or flexing usually have less permanent deleterious effect than much smaller stresses applied for long periods of time. This is exactly contrary to that observed from those types of metals which "fatigue" easily.

Damping Characteristics:

Mention is made of the relatively high damping capacity of plastics compared to metals. This is another property whose implications in design are more far reaching than commonly realized. No material has perfect elasticity; none obey Hooke's law of exact proportionality between stress and strain under alternating force. Most plastics display large deviation from Hooke's law and the associated hysteresis loop may easily be detected. The area of the hysteresis loop, damping, represents energy loss, and is a measure of internal heat generated. Hysteresis damping should not necessarily be associated with weakness of material. In fact, in certain applications it is desirable.

Increased and uncontrolled stress resulting from various vibrations is one of the most common causes of service failure. In low-damping metals, these stresses may reach the fatigue strength and cause failure while certain plastics in similar application may not reach their fatigue points because of the hysteresis and absorption of energy in temperature rise.

It is known, for example, that airplane propeller endurance depends more on damping capacity than on its fatigue strength. Since plastics possess an average damping capacity about ten times that of steel, they are of use in applications where noise is a problem such as in gears.

It should be remembered, however, that high damping also produces internal heat, and as heat affects plastic properties more than it does metal properties a resultant strength drop may occur. This is further exaggerated in plastic application by the low thermal conductivity of the material. A notable example of difficulty because of this characteristic was in the use of synthetic rubber tires where hysteresis and heat build-up produced lower tensile and tear strengths in operation.

In general, it might be said that the superior damping capacity of plastics, which may more than compensate for

[3] Tentative Method of Test for Heat Distortion Temperature of Plastics (D 648–45 T), 1946 Book of A.S.T.M. Standards, Part III-B, p. 872.

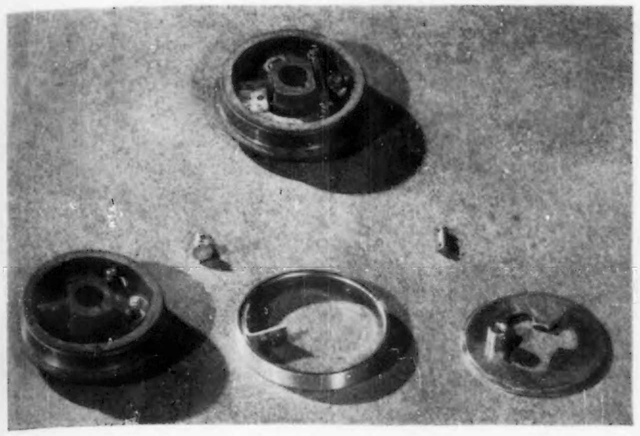

Fig. 1.—Melamine Formaldehyde Speed Regulator.

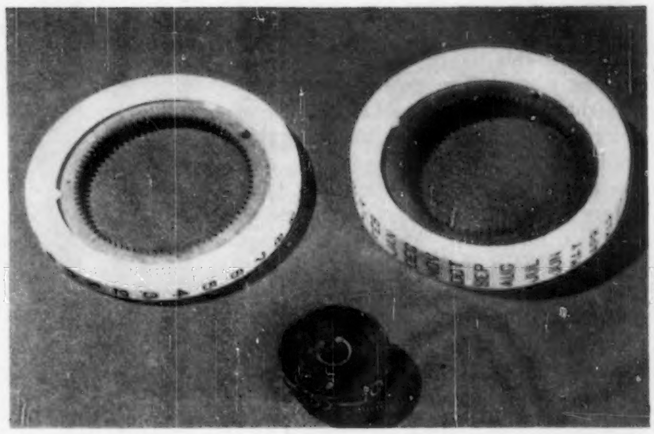

Fig. 2.—Counter Wheels.

their low fatigue strengths, is a desirable feature in aircraft and other members subjected to vibration-inducing forces.

Creep and Cold Flow:

Creep and cold flow of plastic materials are of concern to designers where primary stresses are encountered. When any material is stressed there follows a true elastic deformation followed by a plastic deformation. In the first stage of plastic deformation there is a change of rate with time. This stage is known as "creep." The second has a constant rate of deformation and is known as "cold flow." Such deformation is dependent on stress, time, and temperature. These phenomena occur for all materials, although much more for plastics than for metals. Among plastics, the thermosetting materials are superior, and the reinforced materials are additionally superior. Where primary stresses are to be encountered, if plastics are to compete in major volume engineering applications, the importance of creep and cold flow must be given far more study and under simulated service conditions.

Weathering:

The resistance of plastics materials to weather is somewhat different from that of metals in that their physical characteristics can become appreciably changed under certain weathering conditions without the occurrence of any visible evidence of such changes. Moisture absorption is of little consequence to metals and their applications but is of considerable significance where plastics are concerned. Response in certain plastics to humidity changes can be in a reversible dimensional change as moisture is absorbed and also lost and in a permanent dimensional change which may increase in highly plasticized materials.

A plastic material that is subjected to a forming operation during the manufacture of a part, by casting, stretching, blowing, injection or compression molding, or extrusion, will contain some residual stress within it. There will be a tendency to relieve such a stress by a dimensional change according to the service conditions to which the part is subjected. High temperature and high humidity increase the rate with which these changes take place. The table shows polystyrene to compare favorably with metals while the cellulose materials are adversely affected.

Surface Effects:

Color possibilities are mentioned chiefly because of the disadvantage metals possess in requiring external coatings where both colors and surface protection are required. Surface coatings by nature are generally less permanent than the over-all dense structure of the plastic which enables the color to become an integral part of the plastic product.

For the bulk of engineering metals corrosion is a problem to be combated also by surface coatings, the processing of which causes additional expense not encountered in plastic parts where surface corrosion is not a problem.

Applications

Electrical properties have been mentioned as specific to certain plastics to which metals offer no competition. Typical of this is the speed control device shown in Fig. 1. A melamine formaldehyde plastic is used in this part not only for electrical insulation but for superior arc resistance. Over long periods of time, accumulations of carbon, oil, and dust can collect on the insulating parts. Such contamination serves as a conductor and can cause current leakage which may eventually lead to an arcing condition that normally would cause complete failure when using phenolic materials. The superior arc resistance of the melamine mineral-filled plastic prevents this condition by failing to support arc when the surface contamination shorts.

Figure 2 shows an application where weight is the prime factor in using plastic material. A counting wheel is shown which is one of a great many uses in a single accounting machine. The wheel is a cellulose type plastic injection-molded over a metal gear insert. The characters are paint-filled after molding. The wheel may whirl and reverse its direction as many as eighty times a minute. The operation of the gear requires the use of metallic hardness from the standpoint of wear. The plastic is required because of the amount of inertia to be overcome with a great many wheels operating so many times a minute. Low weight is necessary. The color of the plastic also avoids the necessity of an extra finishing operation

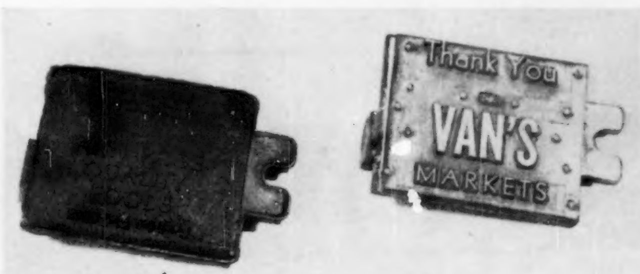

Fig. 3.—Printing Plates.

which would be required in the case of metal.

Also in this figure is shown a metal counter wheel. The small size and subsequent low weight in this case have permitted the use of aluminum for this application. The bearing surface and the wear at the point where the tang enters the hub necessitate the use of metal in this case. Aluminum is used and is anodized, dyed, and subsequently filled for character contrast.

Figure 3 presents an application for plastics which both reduces cost and increases wear of part. In this case we see two printing plates; one made by conventional metal electrotype processes, and the other by injection molding of a vinyl chloride plastic. The electrotype plate is made from the conventional process requiring 21 operations. It is then soldered to the metal plate which has been blanked, formed, and hole punched. The whole metal assembly is nickel-plated to protect against the fatty acid, oil-base, nondrying type inks used in printing from cash register ink ribbons. The second plate is injection-molded into a laminated phenolic matrix which has been molded as a matrix from the original type setup. Both the oil resistance and damping qualities of the semirigid vinyl chloride insure longer life and protection against breakage, while fewer processing operations reduce the cost of the part.

Figure 4 shows three trays from which coin changing is done. All three trays have been used in the same application. It is interesting to note the relative merits of each type of structure. The tray in the center is made of aluminum and is a sand casting requiring some subsequent machining, and also an anodic coating. The tray at the top is one of fabricated steel and is coated with a baked alkyd-type finish. The other tray is plastic, requiring no finishing. The aluminum weighs 1.5 lb., the steel 1.5 lb., and the plastic 1.2 lb., showing that it was necessary to use different amounts of each material to acquire proper strength of the tray.

On a cost basis the aluminum is the highest at a figure of 13, consisting of 6.5 in labor and 6.5 in material; the steel second at 5.4, comprised of 4.4 in labor and 1.0 in material; and the plastic lowest, at 2.8, comprised of 1.0 in labor and 1.8 in material.

So far as utility is concerned the aluminum is, of course, quite resistant to wear from coins although it discolors from both copper and silver. The steel is somewhat subject to wear as far as its coating is concerned and is inferior in this respect to either the aluminum or the plastic. The loss of the coating also permits corrosion of the steel due to humidity or beverages carried by means of coins into the drawer.

Plastic, with color distributed throughout its mass, is quite wear resistant, sufficiently weather resistant, and very good in chemical resistance. Its lighter weight and pleasing appearance, coupled with its much lower cost, have made it a desirable material in an application of this sort.

However, there are applications where special sizes and shapes are required with correspondingly low volume of production. Fabricated steel trays and even wood trays are used in these applications, for high mold cost as well as setup time makes it impractical to attempt to produce molded drawers. Incidentally, in the above application, a general-purpose phenolic in proper design is quite adequate.

The maximum shock encountered is due to the breaking of coin packages across the partitions and the impact of a drawer opening from the spring tension release.

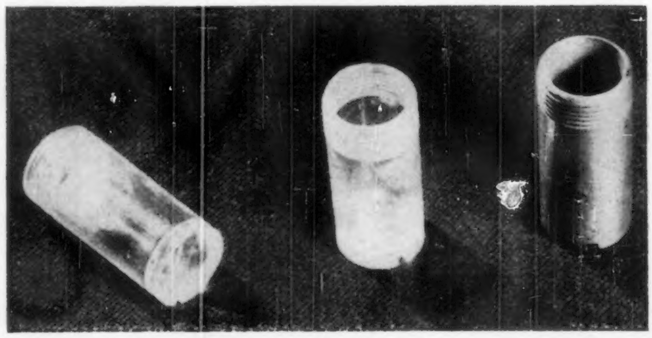

Fig. 5.—Oil Cups.

In Fig. 5 an application for the thermal conductivity property of plastic materials is demonstrated. Two types of cups for motors used on accounting equipment are shown. One of steel is shown which is a typical screw machine part. Also a heat-resistant high-acetyl cellulose plastic oil cup is shown which is an injection-molded product. Transparency was obtained which afforded the opportunity to observe the amount of lubricant remaining in the cup.

A major improvement made by the use of plastic in this application is the insulation, because of low thermal conductivity, of the end of the cup from the heat from the motor. These insulating properties permit the grease to remain at its original viscosity rather than becoming quite fluid as in the case of the metal oil cup.

Figure 6 shows an application where wear is an important factor. The two parts shown are fronts for drawers on cash registers. An open drawer containing coins is usually closed by pressing it with the hand on the front section, which is shown in this picture. The drawer front is a separate part attached to the drawer.

Metal drawer fronts coated with organic finishes have a tendency under

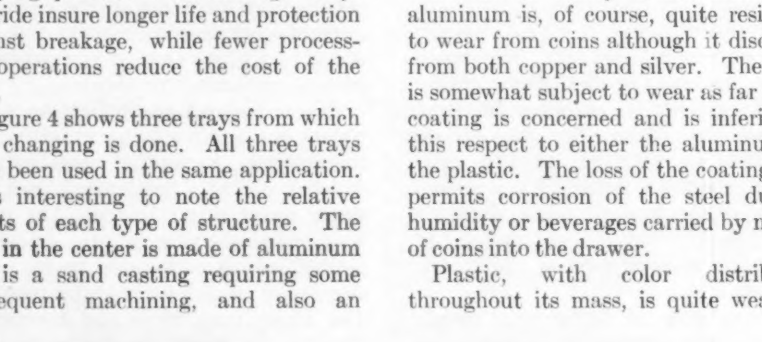

Fig. 4.—Coin Trays.

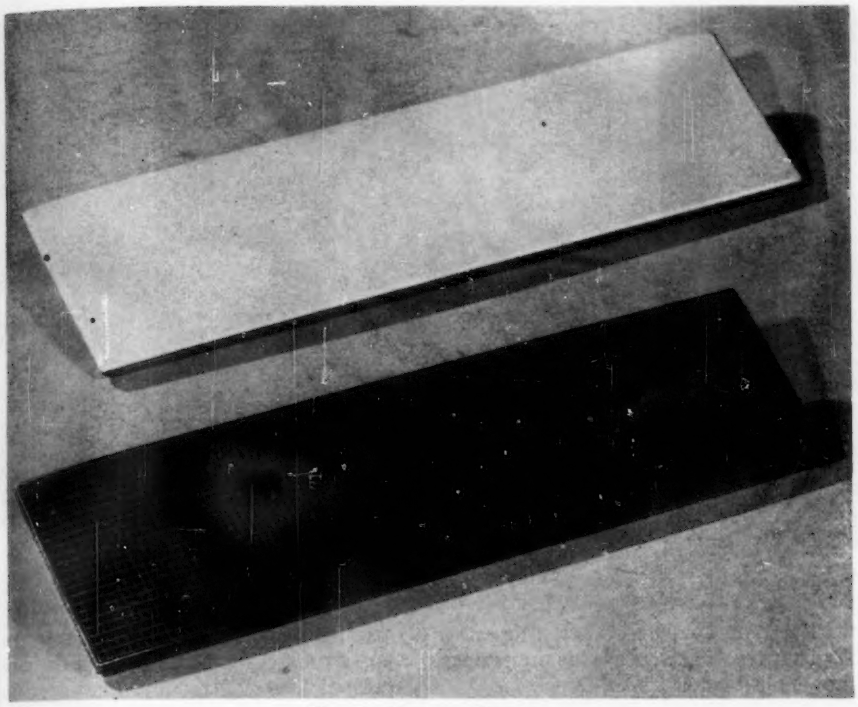

Fig. 6.—Drawer Fronts.

conditions of high usage to wear with a resulting loss in coating in localized spots and possible attendant corrosion. Plastic parts in this application wear extremely well due not only to the fact that the color is distributed throughout the part but that there is a certain amount of flexibility to the plastic.

In an unfinished condition the cost of the steel part would be 2.7, composed of 1.0 in labor and 1.7 in material. However, this cost is materially increased with the addition of several coats of high-grade organic finish resulting in a total cost of 12.7, composed of 11.0 in labor and 1.7 in material, which compares to the plastic cost total of 6.8, composed of 3.3 in labor and 3.5 in material. In other words, specialty finishes for these applications on steel cost considerably more than the basic part, and plastic competes well because of the elimination of finishing together with its improved wear resistance. The relative weights of these two pieces are: steel 0.8 lb. and plastic 0.3 lb. The weight in this case is also an important factor due to inertia to be overcome in operation.

In Fig. 7 are a number of different style key buttons used on business machines. At the left is an injection-molded button, the character being formed in the molding operation. The character is filled with a paint filler and barrel-rolled for cleaning the key. Such keys are used in applications where dirt and wear are not prime factors in operation, for dirt, of course, will fill the recessed character which also is unprotected from wear.

The second key shown is of laminated structure, consisting of a transparent plastic cap, a paper disk with printed matter and adhesive on it, and a preformed button, all three of which are laminated together in a compression-molded operation. Control of all the variables in material is of extreme importance in this structure. Such a key is used where wear and dirt are problems, the transparent cap protecting the character from both factors.

There is also shown a metal key in which is inserted a paper disk for the printing and a plastic or glass disk over the top for protection against wear. The character on the fourth key shown is formed by heat transfer of pigment from a plastic tip onto the injection-molded button, by means of a metal die.

This key has the same limitations as the first one shown in that the surface is not protected from wear and dirt. The last key shown is one which is of considerable interest at present and embodies the double-shot or double-injection principle. In this key is shown the character which is formed in the first injection operation, placed in a second mold and the exterior of the button is injected around it. Keys produced by this method offer considerable protection from both wear and dirt accumulation, inasmuch as the character can be made reasonably thick and it is also flush with the surface of the button. The metal key is the highest in cost at 10.2; the laminated key second at 6.6; the filled key third at 4.6; the heat-transfer key fourth at 2.6; and the double-injection key lowest in cost at 2.2.

In Fig. 8 is shown a typical housing used on cash registers. It is of metal for it is not used for covering alone but as a structural part of the machine. This housing is subjected to considerable shock and abrasion by customers passing the machine, as well as by the action of the operator of the mechanism. Several parts of the machine have to be accessible periodically during the day and this requires doors with locks permitting the operator access to certain parts of the machine for replacement of paper rolls, etc., without access to other parts of the equipment. Delicate mechanism in the top of the machine is protected by a steel housing. The machine is moved from one portion of the store to another and quite frequently from one store location to another. For a device weighing several hundred pounds it is obvious that considerable stress is placed on the cabinet proper during such treatment.

All of these functions of the cabinet indicate that it must have great strength

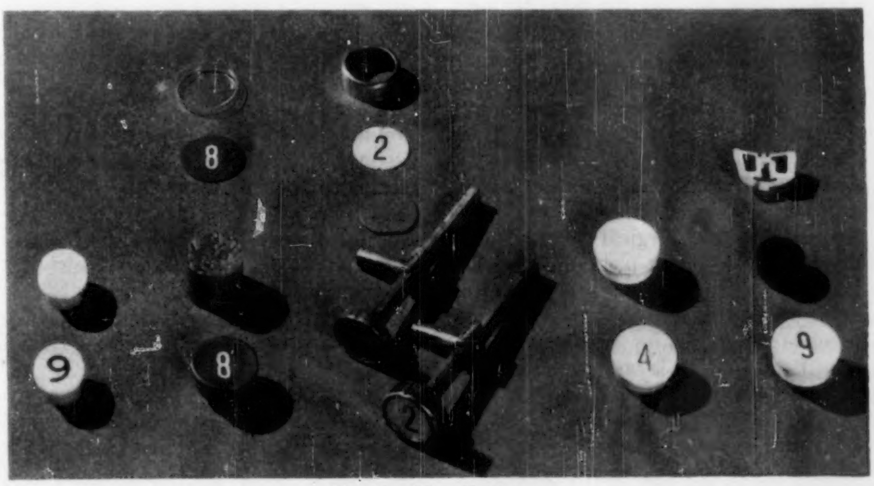

Fig. 7.—Key Buttons.

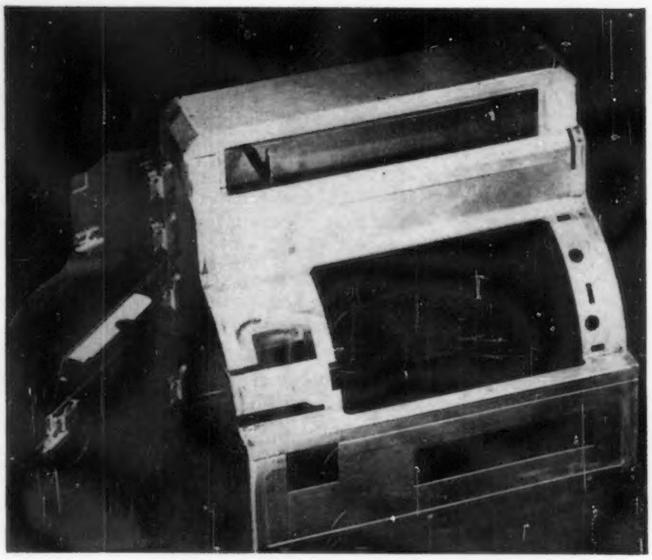

Fig. 8.—Cash Register Housing.

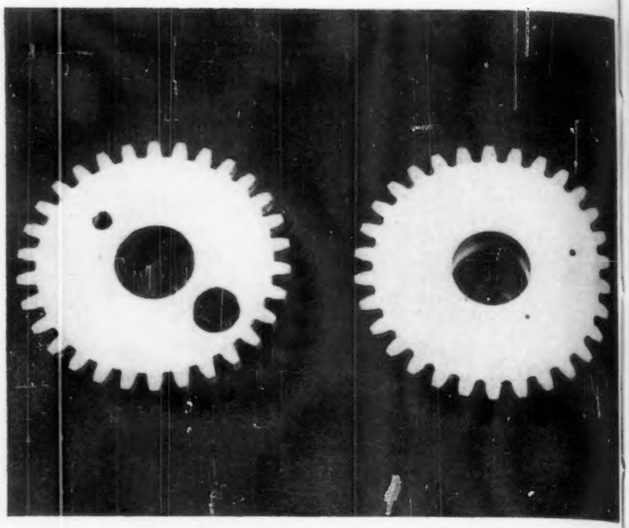

Fig. 9.—Metal Gears.

and shock resistance and that it must be dimensionally stable.

A plastic housing for such a machine would have to be applied over another metal skeleton which would accomplish all of the functions mentioned. This housing would necessarily be removed whenever the machine was handled, as has been mentioned. Flexible mountings would be necessary to compensate for metal and plastic differences in thermal expansion. Resistance to shock would be important and most certainly would necessitate the use of high impact materials whose material and processing costs would raise the price of the product. All of these factors to date have made a practically designed plastic housing for this particular application uneconomical.

It is not my intention to imply that plastic housings are not entirely successful and feasible on other pieces of equipment. Those places where equipment is reasonably light and the internal mechanism is entirely divorced from the housing itself so that the housing may be removed with ease are excellent possibilities for plastics.

In Fig. 9 two metallic gears are shown. Inasmuch as the machining operation of a gear such as is shown to the left is costly, it is quite obvious that a molded product would be desirable if strength properties would be adequate. Several new metallurgical processes are invading the low-cost plastic processing domain. The gear at the right is a molded powdered metal part which can be made at a much lower cost than the gear at the left. It is possible to visualize automatic heat sintering operations which compare favorably in cost to those of plastics. The successful surmounting of the difficulties in this new processing art will provide the engineer with the localized strength properties by heat treating that are his limitations in the plastic field.

Conclusions

The organic plastic materials available to date are limited in their engineering applications when compared to metal. At the same time they have certain characteristics which make them attractive to both designer and engineer, such as low density and electrical properties, ease of fabrication, low thermal conductivity, high damping capacity, available transparency, and low unit cost for mass production items. On the other hand they are inferior to the metals in strength, thermal expansion, modulus of elasticity, cold flow, heat resistance, water absorption, and hardness. They cannot be treated to effect localized change in properties so important to wear of moving parts. At the present time these latter properties are those which are required in most materials for engineering purposes and consequently metal will no doubt retain its position as that most used in the bulk of engineering applications for some time to come.

There is no doubt but that the plastics industry will find far greater outlets for its products in those applications where plastic properties excel with the possibility that with the extension of engineering knowledge for the proper application of these materials, new uses will be found as well. When this is accomplished the proportion of plastics to metals should be much higher than it is today.

The actual price of plastics is a complicated subject, for taking a long view, it cannot be regarded nearly as stable as that of metals. The processes by which metals are obtained and worked are old and stabilized as are also the approximate quantities produced, but plastics are continually increasing in production and, relative to other materials, tending to fall in price.

It is necessary to remember that there are several most important general considerations in the designing of applications for any plastic material which may replace metals, which considerations are not usually found in tabled data:

1. The effect and nature of the application of stress,
2. The amount of permanent dimensional change in time,
3. The required service temperature and humidity range,
4. The previous history of the material, and
5. The effects of change in temperature on physical properties.

To be more specific, it may be said that the engineer must know the function of the part as well as all of the operating and service conditions. No matter how obvious these conditions may appear, it is also obvious that they cannot be correctly and profitably applied unless the engineer has sufficient familiarity with the extensive practical tabulation of chemical and physical characteristics of plastics to be able to evaluate them properly in terms of his problem.

In its proper application there is no substitute for the right material, be it metal or plastic. By right material is meant one which is carefully selected with a particular application in mind, a material that is carefully worked into a design which meets the needs of the user while making the best possible use of the material.

Acknowledgments:

The author wishes to acknowledge the assistance in securing data given him by Mr. John L. Russell, of the Plastics Laboratory, and Mr. Joseph W. Price, of the Metallurgical Laboratory of The National Cash Register Co.

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DISCUSSION

MR. H. M. QUACKENBOS, JR.[1]—Mr. Chollar expresses the opinion held by most of us when he said that plastics will achieve a wider use as more and more is known of their mechanical properties. However, I should like to differ from Mr. Chollar when he laments both the low strength and the low modulus of some plastics. If a plastic part is designed to be as strong as a steel part by providing more material it will often be as stiff as the steel part. This is particularly true in flexural loading where capacity for load depends on the square of the depth and stiffness varies as the cube of the depth. In other words, if you make the plastic part strong enough you do not have to worry about its stiffness.

[1] Bakelite Corporation, Bloomfield, N. J.

The Effect of Fungi and Humidity on Plastics[1]

By John Leutritz, Jr.[2]

NUMEROUS observations and reports by untrained personnel in the Southwest Pacific theaters of war gave rise to the belief that fungi were responsible for the large percentage of functional failures of electrical, electronic, and communications equipment. Since the fungus filaments were observed on the insulating surfaces often bridging terminals, it was concluded that the fungus filaments were acting as conductors and causing low insulation resistance or actual short circuits. It was also assumed that the fungi were damaging the underlying plastic, and that, therefore, it would be necessary to poison all the base materials from which the fungi could or might derive nourishment.

Prior to the recent war, an investigation was conducted on the growth of fungi on paper laminates and their resin components because of similar observations of fungus filaments growing on plastic insulating surfaces. From this research, it was concluded that while the paper by itself would support fungus growth, heavily impregnated paper was not susceptible. Also, the resin components did not offer any nourishment to the growth of the fungi. It was also found that after aging in large humidity chambers, the dust which collected on the surfaces and fingerprint contaminations furnished sufficient nutrient for the growth of several of the common air-borne fungus contaminants. The growth of these fungi, however, was only noted when the relative humidity was at least 90 per cent or over. When communications equipment had been exposed for long periods of time at high relative humidity and even under water, satisfactory functioning of the equipment could be restored by desiccation. Much of the equipment so restored often had the dried filaments of fungus on the insulating surfaces.

To ascertain the effects of these filaments on the insulation properties of plastics, an experiment was set up which fortuitously gave the insulation resistance of the fungus filaments themselves as well as the effect of moisture on different types of commercial insulating plastics. A paper was published by Leutritz and Herrmann in 1946,[3] describing the effect of the fungi on the various types of plastics and the electrical properties of the fungus filaments at different relative humidities. The conclusions of the authors were that the lowered insulation resistance at high humidity is chiefly a moisture phenomenon (Fig. 1). Dust collected on the surface of good insulators causes a marked loss of electrical properties and the decrease is dependent on the relative humidity. Fungi were found to act as dust, but if the dust was not present the fungi were not able to spread across the surface of an inert plastic such as methyl methacrylate.

NOTE:—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at the Symposium on Plastics at a meeting of A.S.T.M. Committee D-20 on Plastics held in Cincinnati, Ohio, March 4 and 5, 1947.

[2] Research Engineer, The Bell Laboratories, Inc., New York, N. Y.

[3] John Leutritz and David B. Herrmann, "The Effect of High Humidity and Fungi on the Insulation Resistance of Plastics," ASTM Bulletin, no. 138, January, 1946, p. 25.

Fig. 1.—Effect of High Humidity and Fungi on the Insulation Resistance of Various Plastics. Temperature 25 C., relative humidity 97 per cent; except where noted otherwise.

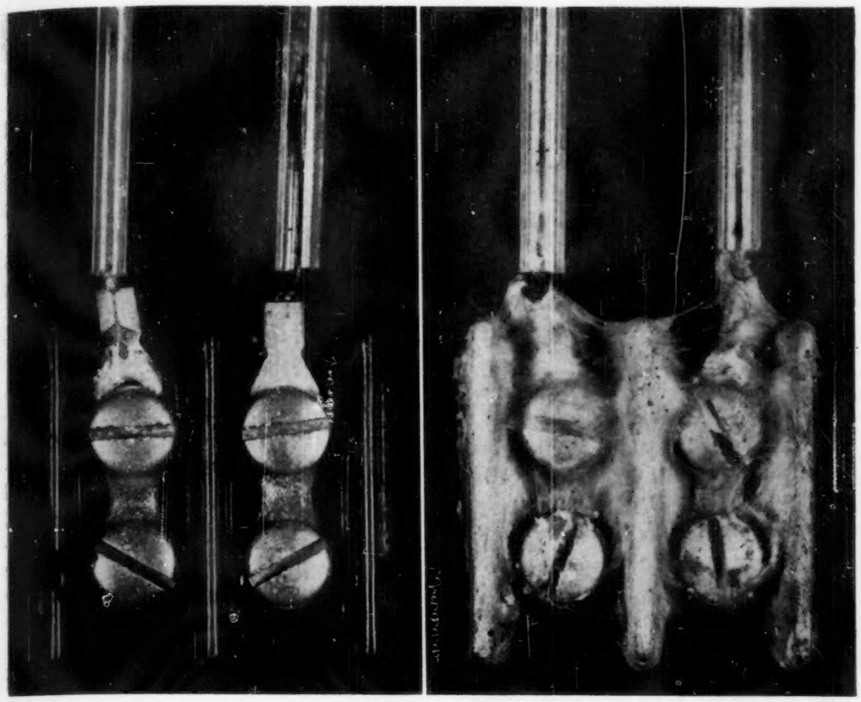

Fig. 2.—Mycelia of the Fungus *Poria incrassata* Which Has Spread from a Vigorous Soil Culture Over the Surface of a Wood Flour Filled Phenolic Plastic. No Damage to the Plastic Was Noted.

Electrical recovery of the plastic over P_2O_5 after long periods of water absorption is largely controlled by its structure. Homogeneous and relatively nonporous plastics such as methyl methacrylate recover immediately. The cellulose-filled plastics recover more slowly, and while some of the mineral-filled plastics recover rapidly, a glass mat laminate exhibited such a slow recovery after a week over P_2O_5 that it was heated 24 hr. at 110 C. This heating brought about complete recovery.

Since the specimens were representative of stock materials, they were contaminated with fingerprints and dust. After exposure for 276 days to fungi followed by cleaning with distilled water and drying, all the specimens showed higher resistance values than initially. Upon reexposure to high humidity, 97 per cent, the rate at which the insulation resistance values fell was somewhat slower than originally. The equilibrium values were practically the same and it was concluded that the principal effect was due to moisture. Microscopic examination of the surface of these specimens showed no evidence of damage, and to verify further the failure of the fungi to damage the plastics, additional experiments were initiated.

These experiments consisted of exposing cellulose (wood flour filled) phenolic plastics to two types of soil burial test. The soil was very active biologically and one in which the presence of wood-destroying fungi had been demonstrated by the exposure of wooden blocks and other cellulosic materials. After 16 to 24 weeks of exposure, wood lost 10 to 40 per cent of its weight, depending on the technique, and was disintegrated, but the plastics showed no changes either in weight or flexural strength, despite a much longer exposure period (52 weeks). Wood flour filled phenolic plastic terminal blocks were exposed to pure cultures of the wood-destroying fungus *Poria incrassata* for 26 weeks. Despite the heavy growth of the fungus, Fig. 2, there was no weight loss nor evidence of fungus damage. This last experiment is additional evidence that the criterion of visual observation is not a sufficient basis for concluding that the fungi damage plastics either electrically or physically. Further experiments along similar lines with different types of plastic, especially those with low resin content and with vegetable type plasticizers, should be conducted.

The exposures should not be on artificial nutrient agar where the moisture variation in the sample often precludes any possibility of damage by the fungi. Soil burial tests using biologically active soil and the wood soil contact culture method would furnish suitable techniques. The criterion for determining damage should be a physical measurement such as one of the following: weight loss or flexural, tensile, or compressive strength. Experiments to date have been primarily with commercially produced plastics with high resin content. It is possible to make a series of laminates with increasing amounts of resin and to determine the minimum amount of resin needed to protect the paper or cellulose filler from fungus damage. Controlled experiments of a similar nature with different types of plasticizers would also yield valuable information.

A single combined field and laboratory exposure was made comparing a para-phenyl phenol formaldehyde tung oil varnish and a cellulose nitrate lacquer containing a mercurial fungicide. Filter papers impregnated with the varnish were completely covered with fungus growth when exposed in a nutrient agar system, but the paper impregnated with a cellulose nitrate lacquer showed a zone of inhibition around the specimen because of the initial, water-soluble toxicity due to the mercury compound. Comparable samples exposed for eleven months in the tropics and then for a month in a chamber at a 100 per cent relative humidity showed the varnish to be free of any fungus growth but the lacquer specimens were completely covered. The tung oil did not furnish sufficient nutrient for the fungi as evidenced by the lack of growth and the mercurial fungicide was not sufficiently stable to protect the cellulose nitrate which offers some food to the fungi.

Field observations by the author on equipment stored under a variety of conditions in the major tropical areas of the world do not substantiate the assumption of fungus damage to plastics. While fungus growth was observed on many types of surfaces including glass and metals, in no instance could the growth of the fungi be shown to cause functional failure of electrical equipment or physical damage either to electrical grades of plastics or even mechanical grades of plastics with lower resin contents.

Analysis of the conditions leading to the growth of fungi on various materials and the engineering considerations may be summed up as follows:

Selection of Materials:

Materials of biological origin—cellulose and leather—furnish food for the fungi and may serve as a focus for the spread of the filaments across fungus inert surfaces. Therefore, the use of the vulnerable materials in the tropics or damp climates should be kept at a minimum. Unless impregnated with a fungicide, functional failure of cellulose and leather will eventually ensue. Materials shown to be unaffected by moisture and fungus should be substituted for these more vulnerable materials.

Design of Equipment:

Many of the fungus troubles which occur are due to poor design. Hermetic

sealing of components, ventilation by heat and blowers or both, will overcome a large part of the fungus and moisture trouble. Insulating surfaces placed in a vertical position remain freer of organic dust and insect debris, which often serve as a focus of fungus infection, than do those placed in a horizontal position.

Packaging:

Vaporproof barriers, specifically, metallic foil and cans, will insure that equipment will arrive in the tropics in satisfactory condition for immediate use. Many packages wrapped with bitumen-impregnated paper and containing silica gel drier were tested with bayonet type humidity indicators. In several instances the indicator showed the relative humidity inside the various layers of wrapping to be at or near 100 per cent, and upon opening the package, free water was often found and the color of the silica gel indicator confirmed the humidity reading.

Maintenance:

During continuous or short periods of intermittent operation of electrical equipment, no difficulties were experienced with moisture and fungus trouble. After long inoperative periods in the jungle, functioning could be restored after the equipment had been dried, oftentimes despite the heavy growth of fungi on friction tape and accumulated insect debris. Daily maintenance and good housekeeping practices aided in the performance of certain types of critical surfaces which were subject to arcing difficulty. The arcing was eliminated by keeping the surfaces clean of any dust.

Use of Fungicides:

Complete elimination of fungus growth from an electrical surface for the service life of the material by the use of fungicides is not a feasible engineering approach nor is it necessary.

Summary

Elimination or mitigation of moisture difficulties will automatically control fungus. Moisture; moisture and dust; moisture, dust, and fungi will cause electrical failure. Fungus without moisture is a fairly good insulator comparable in electrical qualities to cellulose-filled plastics.

Discussion

MR. ROBERT W. AUXIER.[1]—I should like to ask whether Mr. Leutritz found any evidence that fungus grew on various surfaces only after the surface had first been attacked by a bacterium. I have in mind the fact that one could have a surface which was resistant to fungus growth. That surface could become contaminated and covered with bacteria so that the fungus was growing on the substrate formed of the bacteria. The point I wish to clarify by the question is—is it necessary or desirable to use both a fungicide and a bactericide, or is a fungicide alone enough for protection? It is well known that some excellent fungicides are not too good bactericides, while in other cases, the material may be a good fungicide and bactericide.

Mr. Leutritz's paper, in general, substantiates some work that we have done here.

MR. JOHN LEUTRITZ, JR. (*author*).—My opinion is that neither bactericides or fungicides need be added to plastic materials.

[1] Manager, Chemical Dept., Westinghouse Research Labs., East Pittsburgh, Pa.

The Mechanism of Plasticization in Plastics[1]

By J. Kenneth Craver[2]

THE entire plastics industry is based upon the art of obtaining plasticity of one type or another in high molecular weight resins. The resins themselves may be modified by varying the degree of polymerization, by introducing copolymers, or by the use of cross-linking or vulcanizing agents. Once the base resin is prepared, additional plasticity may be obtained by the use of:

1. heat,
2. solvents, or
3. plasticizers (**1**).[3]

The first of these, heat, is used with all the molded resins, both thermosetting and thermoplastic. Thermosetting resins are initially plasticized and then cured by heat. True thermoplastic resins can be plasticized by heat over and over again.

Solvents are employed during the initial compounding of some thermoplastic molding materials (cellulose acetate and cellulose nitrate), and in the manufacture of lacquers and surface coating. Their effect is temporary and once they have evaporated, the resin is left in its original state.

Plasticizers are used to obtain relatively permanent flexibility, toughness, and improved flow. They are chemically related to the solvents; alcohols, ethers, esters, hydrocarbons, amides, and ketones are to be found in both classes. The usual basis for the classification of a compound as a plasticizer or a solvent is the volatility rate—solvents being relatively volatile, and plasticizers, nonvolatile. No strict division can be made, however, as some low-boiling plasticizers are hardly less volatile than some high-boiling solvents. As a class, plasticizers are usually liquids or low-melting solids.

All three methods—heat, solvents, and plasticizers—may be employed during the manufacture or utilization of a given resin: for example, gel lacquers, polyvinyl chloride organosols, and pyroxylin plastics. In most cases only two methods are in use; plasticizers plus heat in the compounding and fabrication of flexible vinyl compositions, rigid cellulosic plastics, hot melts, and plastisols; solvents plus plasticizers in dopes and flexible lacquers.

A consideration of the molecular structure of resins can enable us to picture, in part at least, how these three methods of plasticization operate. Thermosetting resins in their final infusible, insoluble state are held together in a three-dimensional network by primary chemical bonds. Thermoplastic resins, on the other hand, are held together by primary bonds in a longitudinal direction only, the bonding forces in the other two dimensions being van der Waals forces or secondary bonds. These van der Waals forces are of a physical rather than a chemical nature and hence are capable of being modified by external forces more readily than the primary chemical bonds.

The magnitude of the van der Waals forces depends upon the chemical structure of the molecule, ranging from about 1000 cal. per mole in hydrocarbons to 16,000 cal. per mole in amides (**2**). For comparison, primary chemical bonds range from 20,000 to 200,000 cal. per mole.

The long linear molecules of the thermoplastic resins may also be held

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Presented at the Symposium on Plastics at a meeting of Committee D-20 on Plastics held in Cincinnati, Ohio, March 4 and 5, 1947.

[2] Plasticizer and Resin Coordinator, Organic Division, Monsanto Chemical Co., St. Louis, Mo.

[3] The boldface numbers in parentheses refer to the list of references appended to this paper.

together by mechanical entanglement or snarling, but this effect is minor.

At low temperatures, van der Waals forces hold the molecules in a rigid, stiff, and brittle structure. As heat is applied, the initial effect is the loosening of some of these forces and a "sideways" vibration of the molecules. Kinking and some slippage also occur. The net result is to soften and increase the flexibility of the polymer. As the temperature is raised still further, more and more of the secondary valences are disrupted, and at last the entire structure breaks down. The resin becomes soft and is no longer able to maintain its shape. At still higher temperatures, primary bonds will be ruptured with a consequent decrease in molecular weight or even complete depolymerization in some cases.

Solvents modify van der Waals forces, not by overcoming them, but by replacing polymer-polymer bonds with polymer-solvent bonds. The polar groups along the polymer chain attract solvent molecules until the polymer is completely surrounded by the solvent.

As discussed above, a plasticizer can be considered as a high-boiling solvent, and its initial action on a polymer is much the same. It, too, is preferentially attracted to the polymer chain, and both by replacing polymer-polymer bonds with polymer-plasticizer bonds, and by its sheer bulk disrupts the van der Waals forces.

Because of the larger relative size of most plasticizer molecules, it is usually necessary to use either heat or solvents, or both, to aid in loosening up the resin structure during compounding. At high concentrations the plasticizer forms a continuous phase in which the solvated polymer can move. In this case the resulting system is usually a soft gel rather than a fluid solution, as is the case with solvents.

Mechanically, a plasticizer reduces the tensile strength and increases the elongation and elasticity of a resin. In order to have high elasticity, the polymer chain must be able to kink readily. This is true with polyvinyl chloride, but is not so with cellulose acetate. In the cellulose derivatives the chains themselves are relatively bulky and no amount of plasticization can ever lead to as truly elastomeric compounds as can be obtained with more flexible molecules such as polyvinyl chloride.

By decreasing the forces holding a resin together, the plasticizer also lowers the vitrification point (second order transition point). This is the temperature below which the compounds are rigid and break with a brittle fracture and above which they stretch or flex before breaking.

It is generally assumed that plasticizers are attracted to the polar groups along the polymer chain. In order to be attracted, the plasticizer itself should be a polar compound. In practice, we find practically all plasticizers are polar to a greater or lesser degree. The polarity requirements must be modified with the practical aspects of water-insolubility and low volatility in mind. This, in general, eliminates alcohols, acids, amines, and low-molecular weight compounds.

The higher the bonding forces of the polymer, the more polar the plasticizer must be. The following table assumes an average unit chain length of 5 Å and also assumes each polymer chain to be surrounded by four other chains. The polymer bonding forces would then be in the following order of magnitude (**2**):

	Cal. per mole
Polyethylene	1000
Polyisobutylene	1200
Polybutadiene	1100
Rubber	1300
Neoprene	1600
Polyvinyl chloride	2600
Polyvinyl acetate	3200
Polyvinyl alcohol	4200
Cellulose acetate	4800
Polyamides	5800
Silk	9800

Thus, to plasticize polyisobutylene or polybutadiene, one could use hydrocarbons; while polyvinyl chloride, polyvinyl acetate, and cellulose acetate require plasticizers of higher polarity, such as esters, ethers, and amides. Polyamides require extremely polar plasticizers such as phenols and sulfonamides.

The concept of polarity must be modified by some considerations of the molecular size and the consequent compatibility of the plasticizer. Thus, dimethyl and diethyl phthalate are compatible and good plasticizers for cellulose acetate. However, dibutyl phthalate is incompatible and a relatively poor plasticizer. Dibutyl, dihexyl, and dioctyl phthalate are all compatible in polyvinyl chloride, but above dioctyl we approach incompatibility. At the present state of our knowledge, there seems to be no better way to determine compatibility limits initially—as related to molecular weight in a given homologous series—than by trial and error.

One practical way to obtain a preliminary evaluation of compatibility is to observe the swelling action of the plasticizer upon the resin (**3**). Those which swell the resin at room temperature, or slightly elevated temperatures, are usually compatible plasticizers and are called "solvent" types. Those which do not swell the resin are classed as "nonsolvents" and are usually incompatible or compatible to a low degree. However, some nonsolvent plasticizers do have practical utility. In combination with solvent-type plasticizers they tend to increase flexibility without a significant decrease in tensile strength or softening point. The compositions are leathery rather than rubbery.

The final test for compatibility in every case is to make up plasticized compositions and observe them for plasticizer exudation over a period of time and under varying conditions of humidity and temperature (**3**).

The next practical consideration after compatibility is the relative effectiveness of a given plasticizer. Tensile strength (**4**), elongation (**5**), modulus, hardness, and flexibility measurements are all used to indicate this property. It would seem that a test which measures directly the decrease in the bonding forces of a polymer due to the presence of a plasticizer would be highly desirable. Some work has been done along these lines, as follows:

1. The measurement of the viscosity of the plasticizer-polymer system. Low concentrations of polymer may be used or the measurements may be made on normal compositions at elevated temperatures. The various plastometers in use in the industry are examples of the latter type of measurement. The purely mechanical problems of determining accurately the viscosity of a highly viscous material complicate these measurements. The work of Frith (**6**) is an example of the studies being made on dilute solutions of polymers in active solvents and plasticizers.

2. The determination of the vitrification point, or second order transition point. This appears to offer a convenient method of determining plasticizer efficiency. Brittle point, cold-crack point, softening point, and low-temperature flex measurements are all in use. The lowering of these transition points by a fixed amount of plasticizer is a measure of plasticizer efficiency.

The flexibility test described by Clash and Berg (**7**) seems to be particularly convenient in the study of new plasticizers and their efficiency.

3. Dielectric constant and loss-factor measurements on plasticized compositions. The work of Wurstlein (**8**), Fuoss (**9**), Leilich (**10**), and others (**11**) has shown a correlation between plasticizer efficiency and electrical properties. Further work needs to be done but electrical measurements should become an important tool for the future study of plasticizers.

Once a compatible and efficient plasticizer has been found, a number of other requirements must be satisfied before it

is commercially acceptable. These may include, among others, permanence, flame resistance, nontoxicity, lack of color, odor and taste, good electrical properties, low cost, and commercial availability.

Permanence can be considered as a combination of low volatility, high resistance to extraction by solvents, good heat and light stability, and nonmigratory properties. As a rule, the higher the molecular weight of a plasticizer, the lower the volatility. Thus, it is usually desirable to use as high molecular weights as practical within compatibility limits (**5**). Resistance to solvents depends in part upon molecular types—for example, hydrocarbons are resistant to water but not to other hydrocarbons, and ethers are resistant to hydrocarbons but not to water—and in part upon molecular weight the higher homologues of any series being less soluble than the lower.

Heat and light stability depend primarily upon the purity of the plasticizer and secondarily upon the type. Esters are generally quite satisfactory in this respect. The resin itself is a factor to consider. Plasticizers which may be stable to heat and light in the presence of cellulose acetate may be relatively unstable in the presence of polyvinyl chloride. Often specific stabilizers for specific plasticizer-resin combinations must be developed.

Plasticizer migration may occur when one plasticized composition is in direct contact with another. Polyvinyl chloride containing the usual ester-type plasticizers will cause softening of cellulose nitrate lacquers if the two are in direct contact for long periods of time. Nonmigratory plasticizers are to be found among high molecular weight products such as certain thermopolastic alkyds (**12**) or butadiene-acrylonitrile rubbers. These "plasticizers" are of such high molecular weights that there is some justification for calling them modifying resins rather than plasticizers.

The fire resistance imparted to a resin by a plasticizer depends both upon the relative volatility and the chemical structure of the plasticizer and its decomposition products. So far as structure is concerned, certain chemical groupings have been found desirable. These are phosphorus, chlorine, and aryl groupings. The presence of alkyl groups is undesirable. Thus tricresyl phosphate is an excellent flameproofing agent, while trioctyl phosphate adds relatively little to the flame resistance of a resin. Dibenzyl phthalate shows better flameproofing in polyvinyl chloride than does dibutyl or dioctyl phthalate. The chlorinated biphenyls are slightly more effective than the corresponding chlorinated aliphatic hydrocarbons.

Toxicity can be estimated from the structure of the plasticizer, but the final evaluation should rest in laboratory testing—combined with expert evaluation of the results. In general, esters appear to be low in toxicity and some in particular are quite nontoxic.

The color, odor, and taste of a plasticizer are primarily related to its molecular structure, but can be influenced by the purity of the raw materials used and the method of manufacture. Most commercial plasticizers behave quite well in this respect.

The presence of a plasticizer adversely affects the electrical properties of a resin. This is due both to the polarity of the plasticizer and to the increased dipole of the polymer structure caused by the presence of the plasticizer. Highly efficient plasticizers are therefore usually the worst offenders. The best electrical plasticizers appear to be those which have balanced dipoles. Derivatives of phthalic acid, sebacic acid, and other dicarboxylic acids are among the best.

Summary

A plasticizer operates by modifying the van der Waals forces within a resin. Some preliminary estimates of plasticizer compatibility and efficiency can be obtained by a study of the chemical structure, molecular weight, and related properties of the plasticizer. Much more work must be done along these lines before we can predict with very much accuracy, however. Laboratory determinations of compatibility, efficiency, permanence, and performance must still be conducted on each new plasticizer (**13**).

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DISCUSSION

Mr. C. S. Fuller.[1]—I have always been puzzled by the fact that it is apparently easy to find plasticizers for polyvinylchloride which confer rubber-like properties on it whereas it seems to be very difficult to find liquids which act similarly for polystyrene. Does the author have an explanation of this difference in behavior?"

Mr. J. Kenneth Craver (*author's closure*).—Good plasticizers for polystyrene would be quite desirable, and many compounds have been evaluated for this purpose. It has been found by experience that there are a number of plasticizers compatible with polystyrene. A certain amount of these plasticizers can be incorporated into polystyrene without affecting the flexibility to an appreciable extent. As the plasticizer concentration is increased, however, soft, sticky compositions result; thus polystyrene changes rapidly from a rigid plastic to a soft gel over a very narrow range of plasticizer concentration.

An examination of the points of difference between polyvinyl chloride and polystyrene might enable us to explain the difference in ease of plasticization between these two resins. In the first place, polystyrene has a molar cohesion (per chain length of 5 Å) of 4000 cal. per mole, while the value for polyvinyl chloride is 2600. Thus polystyrene has

[1] Bell Telephone Labs., Murray Hill, N. J.

high polymer-polymer bonding forces—similar to polyvinyl alcohol, cellulose acetate, and polyamides, all of them notoriously difficult to plasticize. In addition there are no strongly polar groups in the polystyrene chain to attract the plasticizer. Finally, the bulky, phenyl side groups of the polystyrene chain tend to stiffen the molecule so that even though sufficient plasticizer is introduced to disrupt polymer-polymer bonds, the result is a system consisting of relatively stiff chains almost completely solvated by plasticizer, or on a macroscopic scale, a soft gel.

It is not that there are not plasticizers compatible with polystyrene, but that the internal structure of polystyrene prevents plasticization in the desirable sense of the word.

Service Wearing Tests[1]

By E. N. Ditton[2]

TEXTILE technologists have, until quite recently, been more concerned with developing testing equipment and procedures from the standpoint of the reproducibility of the test or method than in trying to find out whether a given test simulated conditions of service.

To the technicians interested in pure research or those concerned merely with the development of laboratory tests for the purpose of mill quality controls, the essential factor must be the reproducibility of the test method. In recent years, however, technologists have been called upon to develop tests not merely for quality control, but tests that would predict the service to be expected from a given textile manufactured for a specific end use. In such tests, two conditions must be satisfied—not only must the test be reproducible, but it must also simulate conditions which the fabric under test will meet in the service for which it is designed. If the test does not meet both these requirements, it is not good for the intended purpose.

Many examples of such failure come to mind, any one of which will suffice to bring out the point under discussion. For example, in studying the warmth of clothing, a test which measures merely the thermal transmission of a given fabric in still air, no matter how accurately or regardless of 100 per cent reproducibility, will not answer the question, "Will it keep me warm?" This is the type of question which must be answered in tests designed to indicate serviceability.

The realization of this lack of correlation has necessitated the development of service or wear tests and has caused the textile technologist to come out of his laboratory and to study conditions in the field to see just what does happen when, for example, a given garment constructed according to certain specifications is actually worn under the conditions for which it has been designed. Once it is known what type of defect occurs in actual wear, then and only then can a laboratory test be designed to reproduce these conditions.

While the idea of service testing is not new, it is only in comparatively recent years that the need for this development has been realized. The statement is probably correct that it was the necessity of designing proper equipment for the armed forces during the recent war which forced this conclusion upon textile technologists.

At first, it was felt that no great thought had to be expended on either the test itself or upon the interpretation of the results once the test was completed. All that was necessary was to make up a number of garments, give them to people to wear, and tabulate the results. It was soon found, however, that this was not nearly enough and that as many false conclusions could be drawn from such a test as from merely making laboratory tests. Many bitter experiences taught that as much time and truly scientific thought had to be given to the design of a service as to a laboratory test. In other words, while the technician had to come out of the laboratory, he had to bring his scientific methods with him.

In the laboratory when a test method is developed probably the most important factor to be considered is whether it is reproducible. This same question has equal importance in service testing. If a service test is made and item A wears twice as long as item B, but on a repeat test the reverse proves true, then either the test conditions were not the same or the number of wearers were insufficient for statistical evaluation.

It is impossible to mention all the conditions which must be satisfied for a successful service test or to mention all the pitfalls to be avoided and still keep this discussion within a reasonable length, but it is possible to discuss the main conditions which must be satisfied if a service test is to give the information being sought.

In planning a service test probably the first decision to be reached concerns the number of wearers to be chosen. The importance of this choice cannot be overestimated. If too few are chosen, the results will not be accurate, while if too many are used time will be wasted and in many cases the costs of the test will exceed the value of its results. If a statistician is available he should be consulted on this question, but if none is available, the following general rules may serve as a guide:

1. The more closely controlled a group of wearers is, the fewer the number that must be used.
2. In testing a product subject to a great deal of accidental injury, the number of wearers must be greater than in testing a garment not subject to this condition. For example, a test on women's hosiery would require more wearers than one on men's socks.
3. When any doubt exists as to the number of wearers to be chosen, it is advisable to run a preliminary test to obtain some indication of the variations to be expected. From such results a more accurate estimate of the correct number of wearers can be determined.

After the number of wearers has been decided upon, consideration must be given to the "type" of the wearer. People engaged in different occupations will not, in general, wear out the same garment in the same way. For example, a truck driver and an office clerk will not wear out a shirt in the same way. Men with experience in army salvage work will remember that in many cases it is possible to tell a soldier's job from an examination of his trousers, as clerks tended to wear out the seats while mechanics developed holes at the knee. The test group must be chosen by considering just what the test is intended to study.

The test must be so designed that the conditions of wear will be as uniform as possible for all the constructions being tested. Whenever possible, all the test garments should be worn at the same

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[1] Presented at a meeting of A.S.T.M. Task Group H on Abrasion of Section I on Methods of Testing of Subcommittee B-1 on Methods and Machines of D - 13 on Textile Materials held in Philadelphia, Pa., on October 15, 1947.

[2] Research Director, Gotham Hosiery Co., Inc., New York, N. Y.

time. For example, in testing hosiery a pair can be made of two constructions or a shirt can be specially made with sleeves of different materials. Where this is not feasible, great care must be taken in setting up the test to keep conditions as nearly the same as possible. This point must be kept constantly in mind throughout the test. As each item is turned in, the damage must be carefully studied. If the results look out of order, the wearer should be questioned and the data eliminated if the damage were caused by some exceptional condition. For example, a recent hosiery test conducted by the author, when one pair was turned in with an unusual type of damage, investigation revealed that the damage had been caused by the claws of a pet cat.

In setting up the procedure for a laboratory test or a service test, another point to be decided is just what "end point" shall be used. The most usual end points for such a test are:

1. The test may be run for a definite time. For example, if it is desired to test the effect of a particular finish on color fastness or on fabric appearance the test may be stopped after a definite and previously decided upon number of launderings.

2. The test may be run until the first failure of any kind occurs.

3. The test may be run until total failure—that is, until the items are no longer usable. In this case if a repairable defect occurs, the test garment should be repaired and returned to the wearer.

The end point chosen should be the one that will give the best answer to the question for which the test was set up and must be carefully thought out in advance. The method that will serve best for studying the life of a military uniform will be of little help if one is trying to test the snag resistance of hosiery.

The time unit is another very important factor to be considered and one must be chosen that is as exact as possible. If the time unit is too indefinite the results cannot possibly be of much value. For example, the number of days of wear is too inaccurate unless the number of hours for a standard day are determined in advance. Unless this is done a day may mean eight hours to one wearer and as much as sixteen to another. It is preferable, whenever possible, to report the wearing time in the smallest reasonable units.

It is important that simple and detailed instruction be given to each wearer so that nothing is left to the judgment of the individual test subject. This is so obvious that it hardly would seem worthy of mention except for the fact that many otherwise well-thought-out and conducted tests have been rendered worthless because this simple matter had not been taken care of.

The correct analysis and classification of the defects occurring in the service test are one of the most important and, at the same time, most difficult problems in connection with this type of test. Many otherwise well-run wear tests have been of little or no value due to failure at this point. Two main points must be considered:

1. The observers must be carefully trained in advance so that they will be thoroughly familiar with the types of defect to be expected.

2. No matter how well trained the observer, variation in the analysis will occur (particularly if more than one observer is used) unless he has been supplied with very clear definitions of each type of wear that may occur. Wherever possible, it is strongly recommended that either photographs or samples of each type of defect be supplied.

The tabulation and interpretation of results is as important as the test itself. The best conducted test whether in the laboratory or field is of little value if the results are not correctly interpreted. Many serious and sometimes costly errors have been made. This is particularly true if the final construction of a commercial garment is to be determined by the results of a serivce test.

If at all possible, it is desirable to utilize the service of a skilled statistician in the analysis of test results. If this is not possible, the most important danger to be guarded against is the inclusion of results which from the most caual inspection appear out of line. This point has been mentioned before but its importance cannot be overemphasized.

No article can hope to cover the subject of wear tests completely as the field is much too broad both as to types of textile and as to type of information desired, but if this discussion has served merely to point out the most important points which must be considered, and the most common pitfalls to be avoided, it will have served its purpose.

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